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MISSOURI BOTANICAL GARDEN BULLETIN

Volume 59

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MISSOURI BOTANICAL GARDEN

BULLETIN

LIX
VOLUME ~~LXIX~~ NUMBER 1

JANUARY-FEBRUARY 1971

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From The Director

THE MISSOURI BOTANICAL GARDEN is the oldest extant botanical garden in America today. It was founded in 1859 as the Kew Gardens (London, England) of the West. Tower Grove House, Henry Shaw's original country home on the grounds dates from 1849. The museum building from 1859. The administration building has two parts: the north end was Henry Shaw's town house built in 1849 and moved to its present location in 1891; the south end was added in 1908. Many of our greenhouses were built during the period 1912-15. The Climatron, which replaced the old palm house, was completed in 1960.

Shaw's Garden will be here for a 1,000 years to come. Old buildings require constant repair and renovation. We have now nearly completed the job of putting every building in apple pie order. Old iron work has been repaired or replaced. Greenhouses, the Floral Display House, and desert house have new roofs and other parts. New steps adorn the south end of the museum. The main rose garden has a fine fountain and pool at its center and the Lehmann rose garden is set off with a handsome new gazebo.

The grounds are being manicured and an elaborate automatic sprinkler system is being installed around the main entrance flower beds which are set off by the handsome Henry Moore sculptures which were placed there last spring. The rose gardens are among the finest in the U.S. All of this costs a great deal of money, but with your support St. Louis will continue to have the finest botanical garden in the west.

David M. Gates

MISSOURI BOTANICAL GARDEN BULLETIN

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Illustration is from a woodcut of the nettle tree *(Celtis australis)* in William Turner's *A New Herball* published in London, 1551.

Gardening in St. Louis

January and February

RESOLVED: to keep the Christmas poinsettias growing for next Christmas. When plants have lost their bracts, move them to a cool part of basement and water once a month. In May or June move to a sunny spot outside, sink pots in soil, and cut back to six inches. Feed occasionally with liquid plant food and prune as needed for stocky, compact growth. In October, start giving them the short day treatment: indoors before frost, total darkness from 5 p.m. until morning, warm sunny window in daytime. Continue treatment until color begins to show.

Other resolutions worth making: keep a garden notebook of plantings, successes and failures, and maps of your garden to help in selecting seeds and plants for spring from the seed catalogs.

Indoor projects for winter include air-layering lanky house plants; cleaning and repairing tools and lawn mowers; repotting, watering, and feeding of house plants. Another project, especially appealing to children, is starting cacti from seed. Barely cover the seed with soil. Germination may take a while but the tiny plants are worth the waiting and watching.

Outdoor activities include watering of evergreens and shrubs when ground is dry and unfrozen, tamping down soil around frost-heaved plants, and brushing snow off brittle evergreens.

What to use to melt the ice on driveways and walks? Sodium chloride (common salt) can burn plant roots when swept off onto lawns, and ammonium sulphate, although acting as a fertilizer, can hurt concrete. So consider the use of sand or cinders for ice removal instead of either of these.

This is a great time of year to develop an observing eye. Notice the shapes of trees and limbs and manner of growth, their great variety of shades and colors, and watch for steady growth of tree buds. A few branches of alder, birch, redbud, quince, apple, silver maple, or forsythia brought inside to force into bloom will bring springtime a little sooner. □

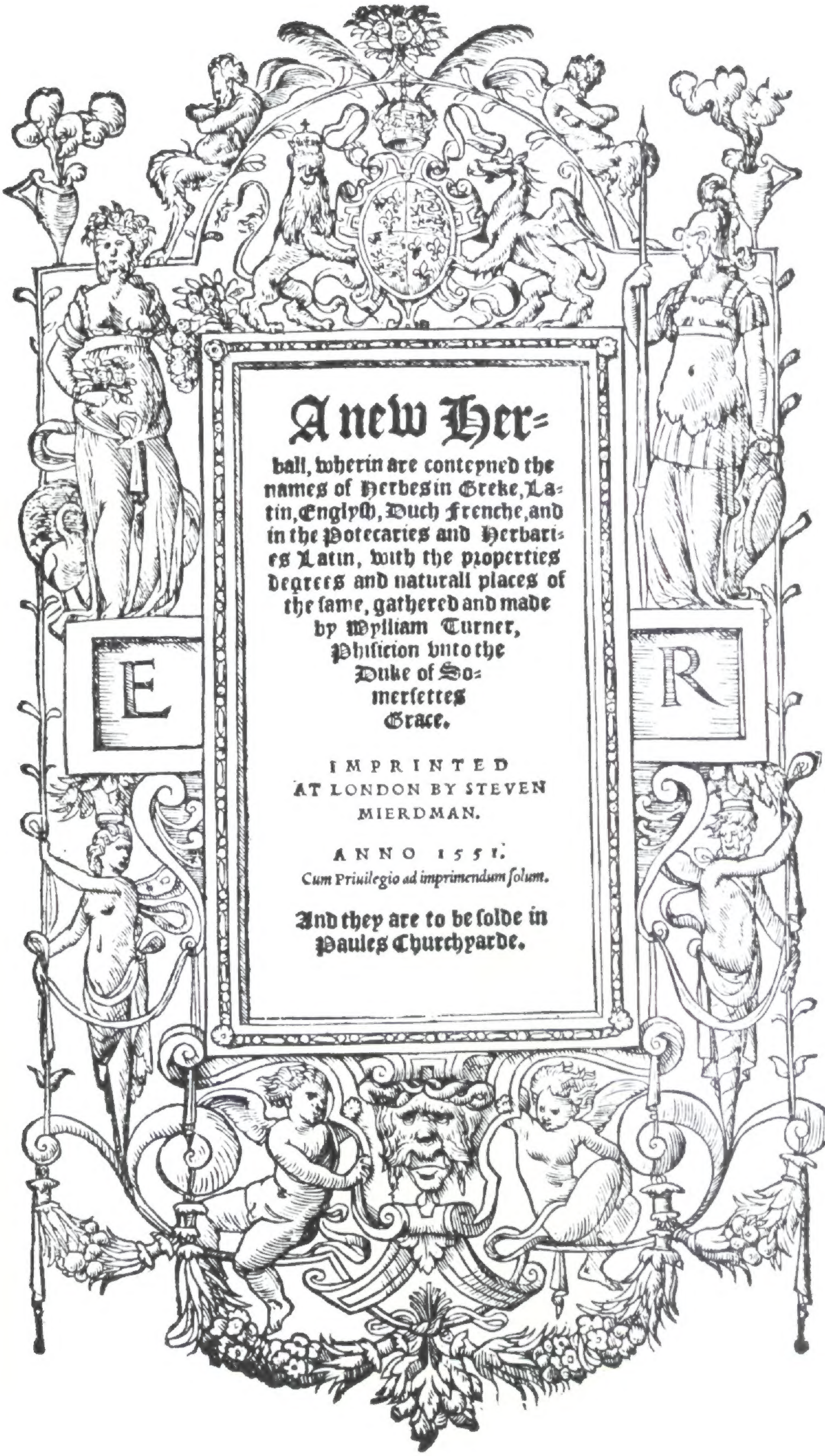
WILLIAM TURNER'S *A NEW HERBAL*

Carla Lange

THE COVER ILLUSTRATIONS for this year's Bulletins will be taken from William Turner's book *"A new Herball, wherein are conteyned the names of Herbes in Greke, Latin, Englysh, Duch Frenche, and in the Potecaries and Herbaries Latin, with the properties degrees and natural places of the same, gathered and made by Wylliam Turner, Physician unto the Duke of Somersettes Grace,"* printed in London in 1551. This work is in the rare book collection of the Missouri Botanical Garden Library.

William Turner, often referred to as the father of English botany, was born probably around the year 1515 at Morpeth in Northumberland, England. He was educated at Pembroke College, Cambridge, under the patronage of Sir Thomas Wentworth, where he was chosen a Fellow of Pembroke Hall. There he acquired a great reputation for his learning and early discovered an inclination for the study of plants and the *materia medica* of more ancient times. Still at Cambridge, he complained: "Being yet a student of Pembroke Hall where I could learn never one Greke, neither Latin, nor English name, even amongst the Physicians, of any herbe or tree; such was the ignorance at that time; and as yet there was no English herbal, but one all full of unlearned cacographies and falsely naming of herbes."

At Cambridge he studied medicine, and became involved with the Reformation as had so many of his contemporaries engaged in



Title page of *A New Herball* by William Turner.

the study of the natural sciences. He became an itinerant preacher making revolutionary speeches in favor of the Reformation. This resulted in his imprisonment, after which he became a voluntary exile from his native country during the remainder of the reign of Henry VIII. This exile certainly benefited his medical and botanical studies.

He lived for a while in Cologne where his studies and observations became the basis of a flora of the vicinity of Cologne. He went to Basel where he became a friend of the great physician and botanist, Conrad Gesner and kept up a correspondence with him. Gesner had a high opinion of Turner as a physician and man of general learning. Later, he became a student of Ghini's at Bologna and received his degree as a medical doctor from the University at Ferrara. This degree was confirmed in Oxford when he returned to England after the accession to the throne of Edward VI, son of Henry VIII and his fourth wife, Jane Seymour. He became physician to his new protector, the Duke of Somerset, and for his theological merits was rewarded by being appointed Cannon of Windsor and Dean of Wells. Being a physician and a botanist as well as theologian was a not uncommon combination at that time.

When, after the death of Edward VI, Mary I (Bloody Mary), daughter of Henry VIII and his first wife Catarina de Aragon, acceded to the throne of England in 1553, Turner left again for Cologne and stayed in various European countries for the duration of her reign. He returned to England after Elisabeth, daughter of Henry VIII and Anne Boleyn, became queen in 1558 and restored all his offices and benefits. The rest of his life Turner devoted to botanical, zoological and ornithological studies as well as to his clerical duties. He created a botanical garden at Wells, formed his own herbarium and also built a second garden at Kew.

Twice his books were banned and ordered destroyed while he was in exile. It is, therefore, not surprising that his works are now exceedingly rare.

Turner's main botanical work *A new Herball* is the only original botanical work written by an Englishman in the sixteenth century. It was published in three parts, the first in 1551, which was dedicated to the Duke of Somerset, uncle of Edward VI. The second part of his *Herball* is dedicated to his other patron, Lord Thomas Wentworth, and the complete work, including the last part, to Queen Elisabeth.

He said that he wrote the *Herball* in English in order to aid the apothecaries who, as he maintained, did not know sufficient Greek or Latin and could use more knowledge of the plants they needed for their concoctions. The *Herball* is arranged alphabetically, and is more original and practical than the more popular publication of Gerarde. The object of an herbal was to determine the plants of the ancients and record their reputed virtues. Turner accomplished this with more caution and discretion than most of his contemporaries and with far less dogmatic confidence and superstition. He was one of the few herbalists who cautioned against any excessive use of herbs. Nevertheless, Turner is the first of the old herbalists who credits the old and widespread belief that the larch was fire-proof.

In the third part, dedicated also to the Company of Surgeons, Turner concerns himself especially with the treatment of medical plants not known to the ancients. For any imperfections, he apol-ogized: "For surely beying to much vexed with sickness, and oc-copyed with preaching and the study of divinitye and exercise of discipline, I have had but small leasure to write Herballes."

Approximately one third of the illustrations used in Turner's *Herball* were borrowed from the prominent physician and botanist Leonhard Fuchs, or possibly even printed from the actual wood-blocks used in Fuch's octavo edition of his herbal *De historia stir-pium* of 1545. However, many of the wood cuts were made specifically for Turner's work.

William Turner was married to Jane Ander, daughter of a Cambridge alderman. Turner died on July 7, 1568, and was buried in St. Olave's Church, Crutched Friars, London, where the grave-stone to his memory can still be seen. He left one son, Peter Turner, who also became a physician though he did not share his father's interest in the natural sciences. However, he must have had some knowledge of plants, since the copy of his father's *Herball* in the British Museum (Natural History) in London contains a long list of errata compiled by Peter Turner for which he apologized in an address to the Reader.

The genus *Turnera* was dedicated by Charles Plumier in Turner's memory, whom he referred to, in spite of his heresy, as "a man of solid learning and justice". The famous Swiss botanist Augustin Pyramus de Candolle used Plumier's genus *Turneria* as the type genus for the family *Turneraceae*.

The Nettle Tree

The cover illustration of this Bulletin is "The Nettel tree or lote tree *(Lotus arbor, sive Celtis)*" (sic) taken from Turner's Herball. Turner says that he himself never saw this plant in England or Germany, but that he saw it in Italy. It belongs to the family of the *Ulmaceae*. The nettle tree *(Celtis australis)* is a native of southern Europe. The flowers open at the beginning of May and the berries reach maturity the following January and stay on the tree until the sap rises in the spring. The wood of the nettle tree is of a dark color, remarkably hard and heavy, tough and flexible and was, therefore, used for making shafts of carriages and hoops of barrels and tubs; in ancient times it was used for making flutes and other musical instruments and in our time is often used by sculptors since it is not easily cracked.

The American nettle tree *(Celtis occidentalis)*, a native of Pennsylvania, was introduced into England in 1656 by the famous gardener John Tradescant. It is distributed in the United States from Massachusetts to northwestern Nebraska, North Dakota, southern Nevada, New Mexico and southwards to Florida, Missouri, eastern Kansas, Arkansas and eastern Texas. It grows usually in rich moist soil, and often, especially in the east, on dry, gravelly or rocky hillsides. Charles S. Sargent, in his beautifully illustrated work *Silva of North America* originally published between the years 1890 and 1902, states of the nettle tree that "Few American trees are better suited to adorn parks or highways; and its value as an ornamental tree is increased by its rapid growth under varied conditions of climate and soil, its resistance to drought, and its freedom from serious diseases and the injuries caused by insects."

In Missouri, the nettle tree, usually referred to as the hackberry or sugarberry, is found in low woods along streams and upland slopes throughout the state. *Celtis occidentalis* var. *canina* is the most common variety in the state. A powder obtained from the dried mashed-up stones of the fruit was used as a seasoning by Indians of the Dakotas. The seeds are so persistent that they are often found in archeological digs. □

BOOKS AND BOOKBINDING

Kendra Deerene Lovette

After the basic necessities of life, nothing is more prescious than books.

Pierre Simon Fournier
(Manuel Typographique,
Paris, 1764.)

SINCE THE BEGINNING of time, man has sought to record his thoughts and deeds for future generations. These records have taken many forms, from cave paintings to clay tablets to the American Indian's bison skins and, after years of evolution, to books made of paper bound together.

Man has used books in many ways: to educate, to put forth new ideas, to repudiate old opinions, and to serve as a source of enjoyment. The Missouri Botanical Garden reference library is primarily concerned with botany, but its objectives are the same as any other library: to educate, inform, and entertain.

Our library contains approximately 65,000 bound books and 100,000 unbound books and separates. These books range in value on the resale market from practically nothing to priceless sums.

All are exceedingly valuable considering the amount of time, space, and money that the Garden has invested in them. In use and availability, each book is considered irreplaceable and is given the best possible care.

Our library has only recently realized the necessity of properly maintaining its collections. Our books had been neglected due to a lack of proper knowledge of what to do and when to do it, as well as a lack of both financial and human resources. Only in the past ten years has there been a concentrated effort to repair the majority of our books.

A hand bindery is necessary to maintain a library such as ours. Many books require special handling; books whose paper will not withstand rough handling, and books that must be signature sewn, rather than side sewn, must be done by hand. The capacity of the Garden's bindery has steadily increased until it is now possible for the staff to do almost any kind of binding and restoration, except for de-acidifying and laminating. Machine binding, because of its speed and economy, is still used to process the latest periodicals into volume form.

One half to two thirds of the collection still needs attention, and the Garden is limited only by the lack of some of the special equipment and personnel to do the work. Our staff consists of two part time binders (William F. Panos and Arpad de Kallos), one part time conserver (Robert A. Mauss), and one full time restorer (Kendra D. Lovette).

Every book that comes into the bindery is analyzed for the extent of damage and the type of repair it should receive. The kind of repair will depend upon the expected use of the book.

A normal rebinding consists of disassembling the book, mending where necessary, resewing the pages, gluing the spine, titling, and casing. Each book needs special attention and rebinding may take from three days to two or more weeks.

A book may come apart easily and need no mending, or it may be torn and require mending on every page. If the pages are fragile, stronger paper is often interleaved for support. A book of single pages or plates may be made into signatures before being sewn.

Claude Johnston

Kendra D. Lovette "side sewing" a book on cords. This is not the most practical or durable method of sewing but is occasionally used when it is important to restore the original format of the book.

Sewing may be done on tapes or cords (raised or sawn-in) and may be done with an individual signature or two or three at a time. Gluing the spine seldom varies but casing may range from simple pressboard covers to heavy davey board. This is the basic routine used on the majority of our books.

In addition, each staff member does specialized work. Bill Panos prepares manilla and bristol board covers for those periodicals which are not bound. Arpad de Kallos does hand lettering and plastic bind-

ing of single sheets into book form. Conservation and treatment of leather bindings is handled by Bob Mauss. Kendra Lovette does the machine lettering and restoration, as well as supervising the conservation program to preserve our rarest and most valuable books.

Proper training is an extremely important, and often overlooked aspect of bookbinding. Improper handling and repairs can ruin books as much as or more than lack of care. Many stores today will not accept books previously "repaired" by haphazard taping and gluing "to hold it together until it can be restored." Knowing what not to do is as important as knowing what to do!

Arpad de Kallos learned bookbinding in his native Hungary and practiced this trade at the Archdiocesan Teachers College of Kalocsa, Hungary and in several of the libraries of Austria and Germany before coming to this country. He, together with the previous librarian, Dr. George B. Van Schaack, instructed Bill Panos in the techniques of rebinding and repair. Bob Mauss studied conservation on his own as well as receiving instruction and supervision from Miss Lovette.

Kendra studied hand binding independently for six years before coming to the Garden, and then received guidance from Dr. Van Schaack. The Garden sent her to New York City in 1968 for nine weeks of concentrated and personal instruction with Mrs. Laura S. Young, President of the Guild of Book Workers. Mrs. Young is a well known binder and restorer, and has taught for thirty years.

While there, Kendra restored six books from the Garden library; attended lectures and exhibits on binding; and studied the allied fields of library science, papermaking, typography, calligraphy, and rare books. Much of the knowledge gained from the course has already been applied to her current work and is of great benefit to the Garden library.

The new library-herbarium-education building, scheduled for completion in 1972, will have the humidity and temperature control so very necessary to the proper care of books. This new housing for

Claude Johnston

William (Bill) F. Panos glues a new mull to the spine of a book to reinforce the hinges. Probably the most common problem in any library is weak or broken hinges because of the enormous stress placed upon this part of the book.

the Garden's library plus the program of binding and restoration will fulfill the two vital needs for the preservation of this priceless collection.

"After the basic necessities of life, nothing is more precious than books" and the most precious books of all are both useful and usable. □

THE GALÁPAGOS ISLANDS
Birds, Beasts, and Botany

Erna R. Eisendrath

IMAGINATIVE TRAVEL INNOVATIONS plus publication of Alan Moorehead's *Darwin and the Beagle* have recently removed the name of the Galápagos Islands from the category of mispronounced gazeteer entries; today almost everybody knows how to speak of them correctly, and many combine this information with the readily associated fact that the name means "tortoise" in Spanish.

Tortoises have been associated with this Pacific archipelago in the minds of sailors ever since its discovery by the Bishop of Panama in 1535. The meat of these huge reptiles is not only edible, but the reptiles themselves keep it fresh when they are imprisoned in the holds of ships for months on end. Treated with proper inhumanity, the tortoises can live for incredible lengths of time without either food or water. And so, for 300 years, tortoise meat was almost the only reason that men purposely visited the almost barren, almost waterless excrescences of volcanic rock that constitute the Galápagos Islands. When Charles Darwin landed on them in 1835 he wrote that

> single vessels have taken away as many as seven hundred, and that the ship's company of a frigate some years since brought down in one day two hundred tortoises to the beach.

Today, as a result of such maritime gourmandism, the Galápagos tortoise population is tragically reduced. Of the fifteen sub-species recognized as having been native to the various islands, two have surely become extinct, two very probably have also become extinct, six others are sorely threatened; and biologists are seriously concerned about four of the remainder.

Fortunately, however, all fifteen sub-species were flourishing when Darwin visited the islands, and this is the reason that they subsequently assumed such an important role in the history of

biology that the redundant phrase "Galápagos tortoise" has become so familiar. When differences among the tortoise populations of several of the islands were pointed out to the young Britisher, his course was set for the intellectual voyage that charted a revolutionary change in biological thinking. Alerted to the anomalous distribution of these animals, Darwin searched out similar discrepancies among other organisms and, in the years after his return to England, these Galápagos collections served as warp for the complicated tapestry of evolution theory. Thus, 300 years after their discovery, these distant and uninviting chunks of land assumed the important role that has distinguished them ever since, that of a living lab for the study of evolution.

It was some years, however, before the significance of his Galápagos finds became entirely clear to Darwin himself. It was not until 1859 that he finally knotted the complex skeins of his thinking into *The Origin of Species by Natural Selection (or) The Preservation of Favorable Races in the Struggle for Life*. He reasoned, in this great book, that

> Species occasionally arriving (on such islands as these) and having to compete with new associates, would be eminently

Erna R. Eisendrath

A typical landing, from rubber boat to lava shore.

liable to modification, and would produce groups of modified descendants.

On the Galápagos archipelago the originally lifeless rocks have come to support a motley crew of plants and animals, all of which reached the islands by merest happenstance, and faced environmental factors entirely different from those to which their ancestors had become adapted. When the new arrivals survived and reproduced themselves, their descendants, even as yours and mine, would have been a variable lot, with some better adapted than others to the conditions of the new habitat. "By means of natural selection" these individuals would have been "preserved" to produce races favored for further survival on the islands. When such favored groups were subjected to the isolating mechanisms that for one reason or another prevented their back-crossing with other groups, the favored races eventually evolved into brand new types of organisms, such as the fifteen sub-species of Galápagos tortoise, as well as the numerous groups (or species) of undistinguished sparrow-like birds that have become a favorite tool in the teaching of evolution theory—the so-called "Darwin's finches."

Erna R Eisendrath

The author was delighted to find one of the endemic composites *(Scalesia)* in bloom.

But the origin of species in the Galápagos archipelago is not limited to the familiar tortoises and finches; other groups of animals also demonstrate the processes of evolution and so do a number of plants. Darwin wrote in his *Journal*, "The botany of this group is fully as interesting as the zoology," but very few people are aware of this. The area has tempted relatively few botanists and, as a result, little has been known about the island vegetation. It is with excitement, therefore, that people interested in the distribution of plants await publication, in early 1971, of the first *Flora of the Galápagos Islands*; and the book is awaited by friends and associates of the Missouri Botanical Garden with special interest and a bit of borrowed pride, since one of its co-authors is Dr. Duncan Porter of the Garden staff. The publishers, Stanford University Press, include not only the work of Dr. Ira Wiggins and Dr. Porter, but also contributions by a number of other specialists; a great number of line drawings, a number of range maps, and photographs in color as well as black and white. The authors give definitive descriptions of all the vascular plants of the archipelago, and their work will be invaluable to serious students of the area; but this study's interest will not be limited to professionals.

Amateurs accustomed to consulting floras of large land areas will be fascinated by the obvious discrepancies in this one. The inquisitive layman will soon discover how relatively few monocots are represented among the 700 or so flowering plants of the islands: there are no native lilies or aroids and, almost incredibly where there are so many hundreds of miles of tropical shore-line, no palms! Likewise, anyone even slightly familiar with the typical flora of the American tropics will be astounded that the Galápagos Islands have no resident members of the rose family.

On the other hand, the pages of the new *Flora* will introduce to the lay public some brand new plants, plants which exist nowhere on earth except on these islands, because it is on these islands that they have evolved. Among them are all the species of four genera of the composite family, all distant cousins of sunflowers. Among them, too, are a number of species of genera (especially of the borage, euphorbia, and acanthus families) quite unrelated to each other in any botanical way. In all, Dr. Porter and his associates estimate that 25-30% of the species of flowering plants that grow natively on the islands originated as species on the archipelago, and this

Erna R. Eisendrath

An endemic cactus *(Brachycereus)* grows from the lava of Hood Island.

fact, in combination with the strange disparities in floral distribution confirm Darwin's suggestion: the flora of the area is just as interesting, and in exactly the same ways, as is the fauna.

Darwin in fact suspected this so strongly that, on his return to England he turned over his plant collections to the great botanist, Joseph Dalton Hooker. Hooker studied them, along with a very few other specimens that were available to him and, in the mid-1840's, read several papers on the subject of the Galápagos flora before the august Linnean Society of London. Himself a great student of plant distribution, Hooker frankly stated that he could "give no clue to the representation of species amongst them; which representation . . . . is a mystery which it is my object to portray, but not to explain."

How fortunate for Hooker that he could with dignity so limit his task! Although Darwin's *Journal* of the Beagle voyage was published at about the same time that Hooker was presenting his work, the great tapestry of evolution was still far from complete, the enigmas of Galápagos life still unexplained, as they would be for some years to come. It has only been since publication of the *Origin of Species* in 1859 that Darwin's solutions to such mysteries as that pointed out by Hooker have been available. During the past century and more his complicated rationale has been accepted, reprinted innumerable times, translated into most languages of the earth, and diluted for popular consumption in any number of books—the latest of which is *Darwin and the Beagle*. Students and laymen of all sorts have been drawn to, in one literary form or another, the intricacies of fact and theory that Darwin was able to synthesize. Such reading can be exciting indeed, but it can in no way compare with the thrill of a visit to the very source of his inspiration.

The Gálapagos Islands were for many years thought by sailors to be enchanted; enchanted by a sort of witchery induced by complicated winds and currents that made landing on them very difficult. For naturalists in more recent times the enchantment has been of a very different sort—but strong, nonetheless. One is lured to land on the very lava fields over which Darwin must himself have had to slither; one observes birds and other animals, as well as plants which are direct descendants of the birds and animals and plants that caused him to jot in his *Journal*, "The natural history of these islands is eminently curious, and well deserves attention."

Much attention has been paid since Darwin's day to the lessons that can be learned from this still living laboratory of evolution, but it will only be after publication of the new *Flora of the Galápagos* that botanists will have a textbook for these lessons in their field. Both professionals and laymen will rejoice that Dr. Wiggins and Dr. Porter yielded to the islands' enchantment: their work will greatly increase the pleasure of others who will subsequently visit the enchanted isles. □

Mysteries and Treasures in Bernhardi's Herbarium

William G. D'Arcy

OVER A CENTURY AGO, when Sir William Hooker of Kew Gardens in England encouraged Henry Shaw to include a library and economic museum in his newly established botanical garden, he also urged that Mr. Shaw purchase a herbarium. The herbarium Hooker had in mind was the large personal plant collection of a recently deceased German professor, Johann Jakob Bernhardi, which was then being offered for sale at a very small price.

Shaw's good friend and scientific advisor, George Engelmann, was in Europe at the time, and Shaw wrote asking him to purchase the herbarium for $600. Towards the end of December, 1857, Engelmann spent a day at Leipzig to conclude the bargain with the heirs, and in due course the result of this purchase arrived in St. Louis to become the nucleus of the Missouri Botanical Garden's now famous herbarium.

Who was Professor Bernhardi to have built a herbarium important enough for the attention of Sir William Hooker? Born in 1774 in Erfurt, Germany, he became a professor on the medical faculty of the former university there and also director of the town's botanical garden. Before he was thirty years old he had published two books on the plants growing around Erfurt, a botany manual and an introductory text on plants. Papers he wrote on plant anatomy gave him a firm ranking with the botanists of the day. He studied vessels in wood and was the first to distinguish clearly between vascular bundles, phloem, and parenchyma, tissues recognized even in elementary botany classes today.

Perhaps more important, at least for building plant collections, he was editor of two gardening magazines. His contacts through these magazines probably did much to help him acquire dried specimens from botanists in other parts of the world. J. J. Bernhardi died in 1850 leaving a herbarium of some 40,000 species which turned out

HERBARIUM
MISSOURI BOTANICAL GARDEN

No 185

Polygala polyphylla DC
South Africa

coll. Ecklon + Zeyher

Type collation

No. 183

Polygala myrtifolia E+
South Africa

coll. Ecklon + Zeyher

Claude Johnston

These two milkwort *(Polygala)* specimens were mounted on the same herbarium sheet with the collectors' tags left in place. The labels at the bottom of the sheet were added after the herbarium arrived at the Missouri Botanical Garden. Ecklon & Zeyher collections in the Bernhardi herbarium include types of many South African species. The purple "Bernhardi Herbarium" stamp is sometimes even fainter than on this sheet.

Claude Johnston

A specimen of buckeye collected by John Bartram which found its way into Bernhardi's herbarium. This sheet was borrowed by C. K. Schneider of Vienna who has annotated it as *Aesculus austrina*, a shrub of the Southeast United States Coastal Plain.

to include over 60,000 specimens. As a token of recognition, the great Berlin garden director Willdenow named a genus of plants *Bernhardia*.

Just what did Henry Shaw get for his $600? Even now, after one hundred and thirteen years, no one knows exactly. After arrival, the specimens were gradually mounted over a period of years, and the total exceeded 62,000. Each mounted sheet was rubber stamped "The Bernhardi Herbarium" in purple ink. Perhaps stamp pad ink was scarce in those days, for on many specimens, the stamp is quite faint, and some sheets missed the stamp altogether.

The specimens themselves are quite good, but the labels are totally inadequate by modern standards and are probably below the standard of labels used a century and a half ago when the collection was amassed. In perhaps the majority of cases, the specimens are identified only by a collector's tag or the small piece of paper with a number, phrase, or name which was affixed to the plant in the field, and which in modern practice would have been replaced in the herbarium by a permanent sort of label on good paper giving the collector's name, the date, locality and perhaps some information about the appearance of the plant. Most of the labels on the Bernhardi specimens consist of small scraps with a scribbled name or number and nothing else. Sometimes there is no label at all, and only guesswork can suggest the collector, era, or locality.

For about thirty years, the Bernhardi herbarium formed almost the entire collection at Shaw's Garden, and containing as it did a more or less world-wide representation of species, it was very welcome. There was little else in America to match it. With George Engelmann's death and the addition of his large herbarium about 1892, dependence on the Bernhardi material lessened, and, as science moved into the twentieth century, only the most determined botanists took the trouble to deal with the uncertainties involved in citing material from it. Even today, much of the Bernhardi material gets only a passing glance from those who can easily work with better material.

But although much of the Bernhardi collection is undefinable in terms of collector or locality, several people in the past have taken pains to make parts of it useful to the modern botanist. By carefully comparing the "tags", which were often printed in the

The Bernhardi Herbarium:

This list gives some sources of specimens, including names familiar to most natural historians.

Bartling, F. G. 1798-1875
Germany, S. W. Africa

Bartram, J. 1699-1777
Eastern United States

Bertero, C. G. L. 1789-1831
S. America, Mexico, West Indies

Bevrich, H. C. 1796-1834
Brasil, Germany, United States

Blanchet, J. S. 1807-1875
Brasil

Brotero, F. di A. 1744-1828
Portugal

Brunner, S. 1790-1844
Africa, Italy, S. Seas, Cape Verde Is., Russia

Carey, J. 1797-1880
United States

Chamisso, L. A. von 1781-1838
Voy. around the world "Rurick"

Cuming, H. 1791-1865
S. Am., Ceylon, India, Malaya, Sumatra, West Indies, Phillip.

Cunningham, R. 1793-1835
Australia

Dregé, J. F. 1794-1881
S. Africa

Duerinck, J. B. 1809-1857
Missouri, Illinois

Ecklon, C. F. 1795-1868
S. Africa, Ascension

Ehrenberg, C. A. 1801-1849
West Indies, Mexico

Flügge, J. 1775-1816
Europe

Fortune, R. 1812-1880
China, Japan

Frivaldsky, J. 1740-1784
Balkans, Crete

Göring, P. F. W. 1809-1879
Japan, Java, Sumatra

Haenke, T. 1761-1817
S. America, Alaska, Philippines

Hornemann, J. W. 1770-1841
Surinam

Hostmann, Fr. W. R. & A. Kappler 1794-1864 1815-1887
Scandinavia, Greenland

Jan, G. 1791-1866
Italy, Sicily

Kinn, M. 17??-18??
United States

Klotschy, J. F. 1805-1860
Europe, Scotland

Kotschy, K. G. T. 1813-1866
Africa

Ledebour, C. F. von 1785-1851
Russia

Lhotsky, J. 1800-1843?
Brasil

Manso, A. L. P. de Silva 1788-1818
S. America

Martius, C. F. P. von 1794-1868
S. America

Muhlenberg, H. E. 1753-1815
S. United States

Nuttall, T. 1786-1859
United States

Poeppig, E. F. 1798-1868
S. America, Cuba

Poiteau, P. A. 1766-1854
Haiti, Guiana

Presl, J. S. & K. B. 1791-1849
Europe 1794-1852

Rottler, Rev. J. P. 1749-1836
India

Salzmann, P. 1781-1851
Brasil

Schiede, C. J. W. 1798-1836
Mexico

Seeman, B. C. 1825-1871
Panama, Mexico, S. Am.

Sellow, F. 1789-1831
Brasil

Sieber, Franz W. 1789-1844
West Indies, Brasil, Africa, Mauritius, New Holland

Tausch, I. F. 1793-1848
Europe

Thirke, Dr. ????-????
Rumania

Vahl, J. L. M. 1796-1854
Greenland

Wallich, N. 1786-1854
Himalayas

Weigelt, C. ????-1828
Surinam

Willkomm, H. M. 1821-1895
Spain

Zeyher, C. 1799-1858
S. Africa

Bernhardi era, by writing to botanists in Europe and elsewhere for handwriting samples, and by studying monographs and other botanical works, a small special handwriting collection was built up and many specimens in the Bernhardi material have been identified with surety in this way. Past directors of the herbarium have played a major part in this, and probably J. M. Greenman in the 1913-45 period had the greatest success. Visiting botanists and even graduate students have played a part in working out the puzzles posed by this large, badly labeled purchase of over a century ago.

And as if bad labels in the J. J. Bernhardi herbarium were not confusing enough, there are specimens from another Bernhardi, Theodore, a nephew, who lived in Germany at about the same time and left his specimens at Berlin and St. Louis!

The question arises whether this difficult identification is worth it, or whether it might be better to forget about the Bernhardi bargain altogether. A look at the success to date is impressive. On page 24 is a list of over fifty of the botanists whose collections have been identified with certainty in the Bernhardi material.

The list includes collectors of many nationalities who collected in many parts of the world. Most important, they were collecting at a time when botanical discovery and classification were proceeding at a rapid pace, and many of the specimens brought in by these collectors became the types for plant species.

Type specimens are the final authority in establishing species names, and must be referred to for determining names when confusion has arisen between species which are too much alike to distinguish apart on the basis of available written descriptions. Not only does the Bernhardi herbarium include a great many type collections, but some of them became unique when their only duplicates were destroyed in Berlin during World War II.

The list of collectors given here is only a part of those whose collections have so far been established in the Bernhardi herbarium. In some cases, only a few sheets have been clarified as belonging to a particular collector; in other cases, the Missouri Botanical Garden has a major portion of the man's collections. The Bernhardi specimens are irreplaceable today, and the progress made so far on them has helped give Henry Shaw's Garden the scientific status it now enjoys. Bernhardi's herbarium includes botanical treasures known to be priceless, as well as many baffling mysteries. □

Asphalt and Artificial Turf

S. Elwynn Taylor and Gerald Pingel

MANY PERSONS ARE SERIOUSLY considering an artificial turf backyard, and although the lover of living things may shudder at the thought of plastic flowers, perhaps plastic grass is not so displeasing to him. We do not intend to evaluate the aesthetic or the economic value of artificial turf, but we have investigated some properties of the turf and find that it may be undesirable in some specific instances.

A newspaper article stating that the turf in Busch Stadium was often too hot for pleasant daytime use prompted us to make a comparison of artificial turf and real grass. We obtained a section of turf and base mat material from the stadium and used it in our study. Comparisons of artificial turf, bluegrass turf, and a piece of asphalt from a crumbling drive were made in our laboratory.

It was expected that the grass would be cooler than the artificial turf because of evaporative cooling resulting from the transpiration process; this was the case. The temperature difference was also influenced by the absorption of sunlight. Measurements of reflected sun showed that grass reflected 2.94 times as much sun-

Ted Cavagnaro

Experiments conducted in the wind tunnel facility showed that asphalt reflected about twice as much solar energy as did artificial turf, and true grass reflected nearly three times as much. The artificial turf becomes much hotter than grass because it absorbs more solar energy and has no evaporative cooling capacity. The artificial turf becomes hotter than the asphalt primarily because of greater absorption of solar energy.

light as did the artificial turf, and the asphalt 1.78 times as much. The absorptances to sunlight were grass, 78.4 per cent, asphalt 87 per cent, and artificial turf 92.7 per cent.

The experiment was conducted in early October, so the sun was not as intense as it sometimes is in mid-summer. The air temperature was 32°C (90°F) and the relative humidity was 40 per cent. The wind was 50 cm sec^{-1} (1.1 mph).

Gerald Pingel

An infrared device is used to compare the temperatures of asphalt, artificial turf, and lawn grass. The artificial turf was much warmer than either the asphalt or the lawn.

The grass was near 38°C (100°F) and the asphalt was at 60°C (140°F). The artificial turf heated to 72°C (162°F)! No wonder the ball players occasionally feel uncomfortable when playing on the artificial turf. It is hotter than being on an asphalt field.

Asphalt has a definite effect on the city. First, it replaces plants and forms what some have called an "asphalt desert." The asphalt contributes to the sweltering heat of the city and may actually be responsible for some of the extreme high summer temperatures. Asphalt is not generally considered attractive; further, the plants that are removed when asphalt is laid are not just a loss of beauty, but are in a sense air conditioning units lost to us. Living plants can serve to cool the air by the process of evaporation and freshen it by removing some pollutants from the atmosphere (e.g. fluorides, NO_2 , SO_2 , and O_3).

Replacement of lawns with artificial turf may be more attractive than replacement with asphalt, but the effects on our environment are very similar to those of asphalt. A patio of artificial turf may provide a very pleasant environment, especially on cool but sunny fall and winter days. The warmth of the turf would certainly not be unwelcome at these times. However, in the heat of the summer, the area may be uninhabitable when the sun strikes it. □

ORCHARD GRASS

Orchard grass (*Dacylis glomerata*) does indeed grow in orchards, as in many other shaded areas, so that the American common name is an appropriate one. However the name used in England is even more descriptive and it seems a pity that it somehow got lost in crossing the Atlantic. It is called "Cock's foot grass" there, a truely descriptive name; the grass florets are packed into little wads that resemble the blobs of flesh, covered with tough skin, on the foot of a chicken. The scientific name *Dactylis* refers to this same feature; it came from the Greek word for finger.

Thoughts on Foundation Planting

Paul A. Kohl

A NEW RESIDENCE or an older one is often in need of a neat, reasonably trouble-free, group of plants to improve the appearance of the home. "Foundation planting" is the term usually used in the broadest meaning of the expression. One can sympathize with a person who is confronted with such a problem but who knows very little about plants. Possibly he has noticed some brilliant red azaleas in front of a number of homes in April so he thinks he has the answer—why not plant azaleas? But he must realize that they bloom for only two or three weeks and look better when combined with other plants.

Obviously it would be better to select plants that are presentable throughout the year. To attain such an effect it would be well to consider the evergreens, broad-leaf and needle types, that retain their leaves throughout the year. They do shed their foliage each year but so gradually that it is hardly noticed.

The deciduous shrubs differ from most of the evergreens in that they need some yearly pruning to keep them in good condition. If neglected they soon become overgrown. Unfortunately, a new problem has arisen with regards to the disposal of prunings from

shrubs. They may not be burned and trash collectors will not pick them up unless they are bundled. This a chore and a mean one if thorny plants like barberries are bundled.

The foundation planting picture features a good combination of evergreens which have been in excellent condition for many years. For a large plant American holly is a good subject. Berried hollies are preferred but a staminate tree will be needed in the area to insure a good set of berries. The reason is that staminate and pistillate flowers, male and female, occur on separate trees and both kinds are needed so that bees will be able to pollinate the female flowers.

Paul A. Kohl

Foundation planting of American holly, yew, ivy, and periwinkle.

American holly has been growing in St. Louis gardens and parks for many years indicating that it is a good plant for this region. It needs good soil and the addition of peat in the mixture at the time of planting will be beneficial. Hollies are fed once a year in early spring with a lawn fertilizer or an azalea-camellia formulated product. Cottonseed meal and flowers of sulfur spread around the base of the hollies every two or three years will prevent a chlorotic condition which sometimes occurs.

Yews are excellent plants and should be planted more often. There are spreading types like the Japanese yew and also various upright forms like Hicksii and Hatfieldii. The spreading yews may be left to grow naturally or sheared to keep them within their allotted space. The upright-growing varieties may be trained into globes. Yews have no special soil preference such as the slightly acid soil needed by the hollies. The only requirement is good soil with leaf-mold or peat added at the time of planting.

Occasionally a yew might lose its lustrous green color. This may be due to poorly drained soil or tiny, black ants which could be gnawing at the roots. If ants are present, a little chlordane worked into the soil near the roots should stop them. In the spring the yews will send forth many new growths. If the plants have attained the desired height these shoots are cut away with shears. A second growth develops by mid-August and this too is removed. This twice-a-year shearing is the only attention the yews need. They should be fed once a year in spring with a commercial fertilizer.

The ground-cover plants, as seen in the picture, are common periwinkle, or running myrtle as it is known, and English ivy which grow well together, the ivy being the predominant plant and the vinca giving a welcome touch of blue when it blooms in early spring.

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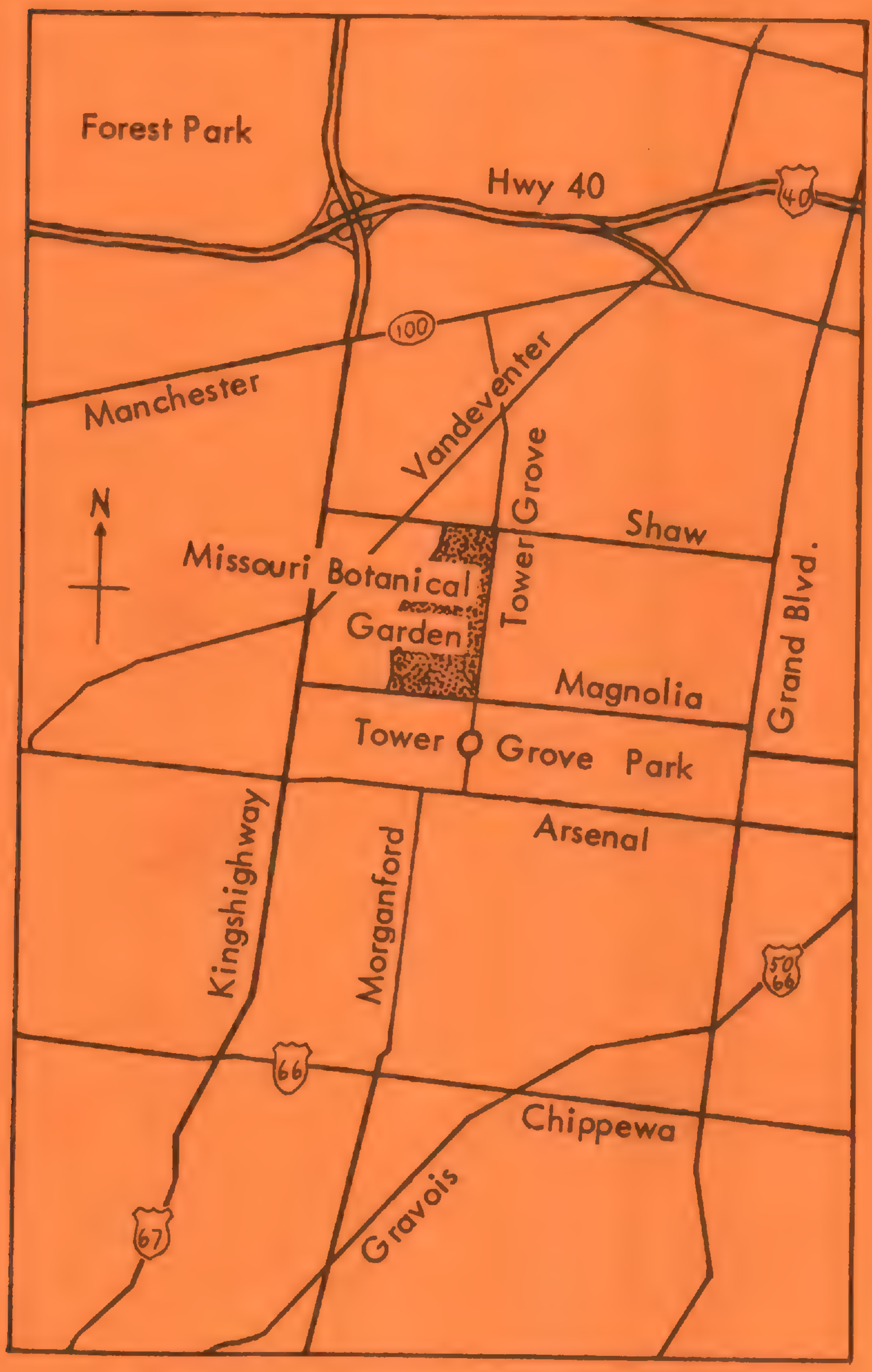

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MISSOURI BOTANICAL GARDEN

BULLETIN

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MARCH-APRIL 1971

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From The Director

THE VICTORIAN INFLUENCE of the Nineteenth Century was very strong in this country at the time that the Missouri Botanical Garden was being established by its English founder, Henry Shaw. This era's emphasis upon gracious living and a highly ornamented style of architecture and decor is apparent in the Garden even today.

In 1849, Henry Shaw built his city house, now the Administration Building, as well as his country home Tower Grove in the Victorian tradition. The Mausoleum Grounds with its ornamental iron fence, the massive structure of the Main Gate, the Museum, and the Linnaean House are also consistent with the Victorian Age.

During this time, British high society became very fond of ferns which are highly ornamental in a way that compliments the style of the era. This special *Bulletin's* emphasis upon ferns and the special exhibits on ferns were inspired by *The Victorian Fern Craze*, a book written by David Allen and published in 1969 by Hutchinson and Co. Publ., Ltd. It is a book concerning the history of "pteridomania." The Garden Library possesses most of the books published about ferns during this period.

Ferns, among the oldest of higher forms of land plants, are delicate and esthetically attractive. They generally grow in damp, shaded places which is why they are easy to grow indoors and in terrariums.

David M. Gates

MISSOURI BOTANICAL GARDEN BULLETIN

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Cover design by Peter Geist. Photocopy by Todd Studios. Illustration is from the facsimile reprint of the *Codex Dioscurides, Anicia Juliana*, originally written in the sixth century.

Maidenhair Fern (cover)

Carla Lange

THE COVER ILLUSTRATION of this Bulletin is the earliest extant picture of the maidenhair fern, *Adiantum Capillus-Veneris* which was taken from the facsimile reprint of a manuscript of one of the oldest herbals still in existence, the *Codex Dioscurides, Anicia Juliana,* or commonly known as the *Vienna Dioscurides* since it was part of the Austrian Court Library in Vienna for many centuries and is now housed in the Austrian National Library where the facsimile copy was made. The *Codex* contains the earliest plant pictures that have come down to us, about ten of which illustrate ferns.

According to the dedication picture in the *Codex,* it was commissioned to be written during the first decade of the sixth century by the citizens of Honoratae (now known as Pera and part of the city of Istanbul) and presented as a gift to the Princess Anicia Juliana to express their gratitude for her donation of a church for their town. This dedication picture is probably the earliest illustration of a book dedication. It shows the Princess Juliana in a purple tunic with gold embroidered sleeves, purple shoes and a cap of the same colour with pearls and a golden clasp, wearing earrings with one large pearl in each. The Princess was the daughter of Flavius Anicius Olybrius and his wife Placidia, daughter of Valentinian III, emperor of the West from 425 to 455 A.D. In 480 she married Flavius Areobindus Dagalaifus and had one son, Flavius Olybrius Anicius who later became a Roman Consul. Princess Anicia Juliana died at the age of 65, with the reputation of a very pious person, deeply interested in theology, benefactress of the poor who built and had restored many churches in Constantinople.

It is not known what the princess did with this valuable *Codex,* whether it was kept in her family after her death or whether it was made part of the Imperial Library or whether she gave it to a monastery or a hospital. However, after the crusaders took Constantinople in the thirteenth century and after it was successfully

reconquered, the *Codex* seems to have been kept in a monastery in Pera for generations until the fall of the Roman Empire in 1453 when the *Codex* fell into the hands of the Turks. The physicians of the conquerors now in power, however, were well aware of the value of this work and the use they could make of it in their profession.

To its original descriptions of plants in Greek, they added Arabic, Persian and Turkish synonyms and during the sixteenth century, when it was used by the Jewish personal physician of Sultan Suleiman II, he added his translation of some of the plant names in Hebrew. His son sold the *Codex* in 1569 to the Austrian Imperial Ambassador who bought it for Emperor Maximilian II for one hundred gold ducats and this valuable work became part of the Vienna Court Library.

It became soon known to the famous botanists of this time that the *Codex* was now in Vienna and Dioscurides' plant descriptions and the "vertues" he ascribed to them were mentioned by many of them in the herbals they published, including the well-known Belgian botanists Rembertus Dodonaeus and Carolus Clusius as well as the English botanists Gerard, Parkinson and others.

The largest part of the *Codex* consists of full-paged illustrations of plants with descriptions in Greek to which later synonyms in various other languages were added. Most of the descriptions of plants in alphabetical order were taken from manuscripts of the Greek physician Pedanios Dioscurides who was physician to the Roman troups under Nero which he accompanied throughout all parts of the Roman Empire, using this opportunity for an extensive study of plants, minerals and other objects in nature which aroused his curiosity and interest.

The plant of the cover illustration was originally described in Dioscurides' work *De materia medica*. The following comes from the only English translation of *De materia medica* made in 1655 by John Goodyer, edited and last printed in 1933 by Robert Gunther, reprinted by Hafner in 1959:

ADIANTON. *Adiantum Capillus-Veneris*
(*Asplenium Trichomanes* (Penzig))

Adiantum, which some call Polytrichon (some Callitrichon, some Trichomanes, some Ebenotrichon, some Argion, some Coriandrum aquaticum, the Egyptians Epier, ye Romans Cincinnalis, some Terrae Capillus, some Supercilium terrae, ye Dacians Phithophthethela) hath little

leaves like Coriander, jagged on the top, but ye little stalks on which they grow, are black, very thin, a span long, glistning. The leaves like to Filix, very small. But it bears neither stalk, nor flower, nor seed: ye root is unuseful. The decoction of ye herb being drank is of force to help ye Asthmaticall, Dyspnaicall, Ictericall, Splenicall, dysureticall. It breaks also ye stones & stays ye belly, & helps ye venemous-beast-bitten, & ye flux of ye stomach, being drank with wine. It drives out also ye menstrua, & after purgaments. It stays also ye spitting up of blood. It is smeared on also raw, for venemous-beast-bitten things & thickens ye Alopeciae, it disperseth ye Strumas: with Lye, it wipes off ye furfures & ye Achores. But with Ladanum & with Oleum Myrtinum & Sufinum, or else Oesypum, & wine it staies ye falling hair; & ye decoction of it being rubbed on with Lye & wine doth the same. And it makes cocks and quailes ye more fighting when mixed with their meat. But it is planted for ye sheep about sheepcoats. It grows in shady and marshy places, and moist walls, & about fountains.

Adiantum Capillus-Veneris is a native of the southern part of France and the Mediterranean countries where it grows on rocks and used to be found in old ruins. From there it was brought to England for medicinal purposes. It is one of the rarest and most local of British ferns, growing only on some cliffs or rock in Scotland and Wales. It is a perennial with fibrous, tufted and shaggy roots and produces spores from May to September; being a very succulent plant, it yields almost its entire weight in juice, but has neither taste nor smell. It can be preserved in pots with gravel and lime-rubbish in which it will thrive much better than in good earth.

Its common name is the true maidenhair, called "true" because among some half a hundred species of *Adiantum*, the original name given by Dioscurides, the *Capillus-Veneris* gave the name of maidenhair to the whole genus. On the American continents it is found from south of the Amazon River to north of the Potomac River. Dr. C. C. Parry in his *Botanical Observations in Southern Utah* published in the *American Naturalist* in 1875, says: "Apparently quite out of place in this arid climate, we notice quite frequently on the perpendicular face of moist sandstone rocks *Adiantum Capillus-Veneris*." It grows wild in almost all states of this country, however, it does not endure the cold winters of the Northern United States. □

The Truth About Ferns

Kenneth Peck
Illustrated by Sandra Thornton

IT MIGHT BE SAID that much of our ignorance is couched in an inability to see the truth of a matter clearly. We feel compelled to "innovate"and then elaborate on what is considered fact and sometimes emerge with a fantasy requiring more faith to accept than the actual facts themselves. In a later article which deals with fern lore, some of the delightful fantasy surrounding human associations with ferns will be unfolded, but here we will delve into some of the tangible aspects of the fern's life history and botanical relationships.

Ferns hold a curious position in the plant kingdom. On one hand, they assume a moss-like stature in some forms, but on the other hand, a number of tropical forms become tree-like and grow 45 to 50 feet high. One of the baffling things about ferns to early botanists must have been the combination of the fern's possession of a conductive or vascular system and total lack of any seed-producing structure like a flower or cone. How can a plant grow to a good size like other plants in the forest and not produce seeds? This is the point at which we can refer to ferns as "Vascular Cryptogams." The meaning of the first term is clear now, but the second one, "cryptogam" has reference to the manner in which ferns reproduce. Trees like oak, maple, and pine all produce seeds in addition to having a well-developed vascular system. They are, in fact, about 95% vascular system which to some extent accounts for their occasional great size. Some vascular plants, like the floating duckweeds, are very small though, and scarcely exceed a 2 mm. diameter. Going in another direction, we encounter the mosses which not only lack flowers and the ability to produce seed, but have no appreciable vascular system. Their constituent parts, therefore, are considered only analogous to the leaves, stems, and roots of vascular plants and they are never of any height greater than about 24 inches. The following tabular summary will help visualize these things collectively.

	SEED PLANTS	FERNS	MOSSES
Flowers	Yes	No	No
Cones (a)	Yes	No	No
Seeds	Yes	No	No
Vascular system	Yes	Yes	No (b)
True leaves	Yes	Yes	No
True stems	Yes	Yes	No
True roots	Yes	Yes	No (c)
Spores	No (d)	Yes	Yes

(a) Bearing seeds, i.e.
(b) Vasculation evident in some forms
(c) Rhizoids are analogous to roots in mosses
(d) Pollen grains and embryo sacs are considered to be types of spores which produce the sex cells that, upon union, give rise to the seed embryo. Fern and moss spores never produce seeds and are never sexual.

The life history of a fern is well known to students of botany and is usually presented in typical "cycle" form. I prefer to think of this as a linear process and the accompanying illustration of a "typical" fern's life history will demonstrate this. The spore, temptingly analogous to the seed, seems to be a logical place to begin, although it might be more appropriate to begin epic style in the middle of things, and deal with the development of the fern embryo. Let's take a spore anyway—one that has fallen to the ground in a good location. (Since the following description involves terminology that may not be familiar to all, your attention is directed to the etymological glossary on page 27. I think this will add meaning to your understanding.)

The germinating fern spore produces a short, green filament, the *protonema* (Fig. 1B), which abruptly expands into the relatively broad leafy structure called the *prothallus* or *prothallium* (Fig. 1C). Here is where the action is and where the term "cryptogam" has its application. In the early confusion about ferns, sexuality was not recognized and the prothallus was truly considered to be the first leaf on a young fern instead of the plant on which reproductive structures were formed. The term "cryptogam" means rather literally "hidden marriage." The agents of reproduction—sperm and egg—

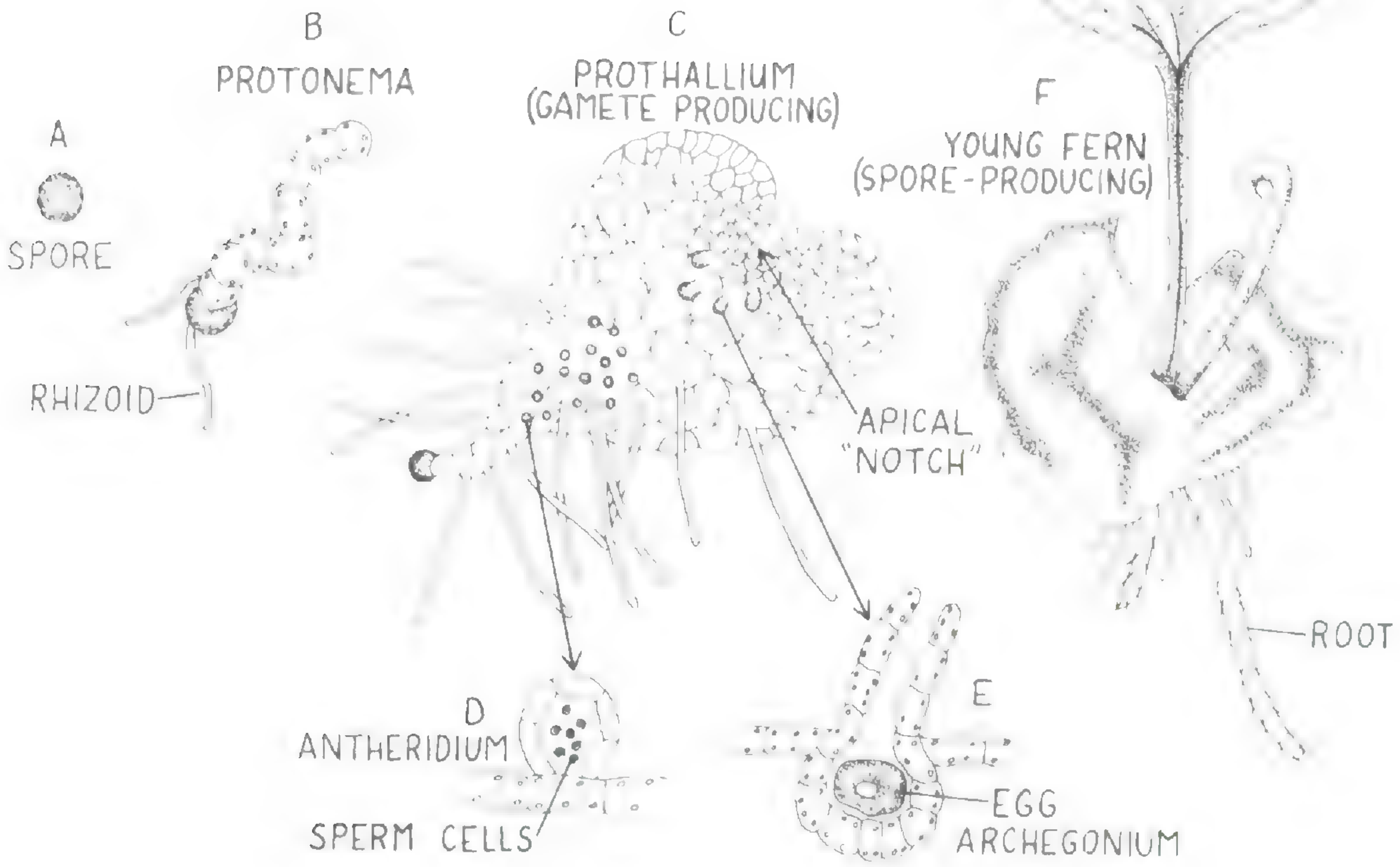


Figure 1. Typical fern life history. See text.

are contained within microscopic structures quite appropriately specific to each. Sperms are produced by the antheridium (Fig. 1D) and the egg by an *archegonium* (Fig. 1E). Each structure encloses its contents with a single layer of cells. When mature, the antheridial jacket ruptures when flooded with water causing the release of numerous, minute, motile, sperms usually in a matter of minutes, whereas the archegonium may take one or two hours to open. Swimming randomly at first, the sperms are eventually drawn to the archegonia by a chemical attractant secreted by the latter. Several sperms may enter an archegonium, but only one sperm actually fertilizes the egg.

The new body formed by the union of egg and sperm ("syngamy" in text book parlance) is called a *zygote*. The latter becomes the *embryo* of a new fern plant which soon proceeds to the business of producing green leaves bearing spores, and growing separately from the prothallium.

The fern leaf, termed a *frond*, arises from a typically horizontal rootstock. The frond is variously cut and divided into lesser parts, with an appropriately descriptive terminology. Frequently seen on the underside of fern frond (Figure 2) are round or elongate struc-

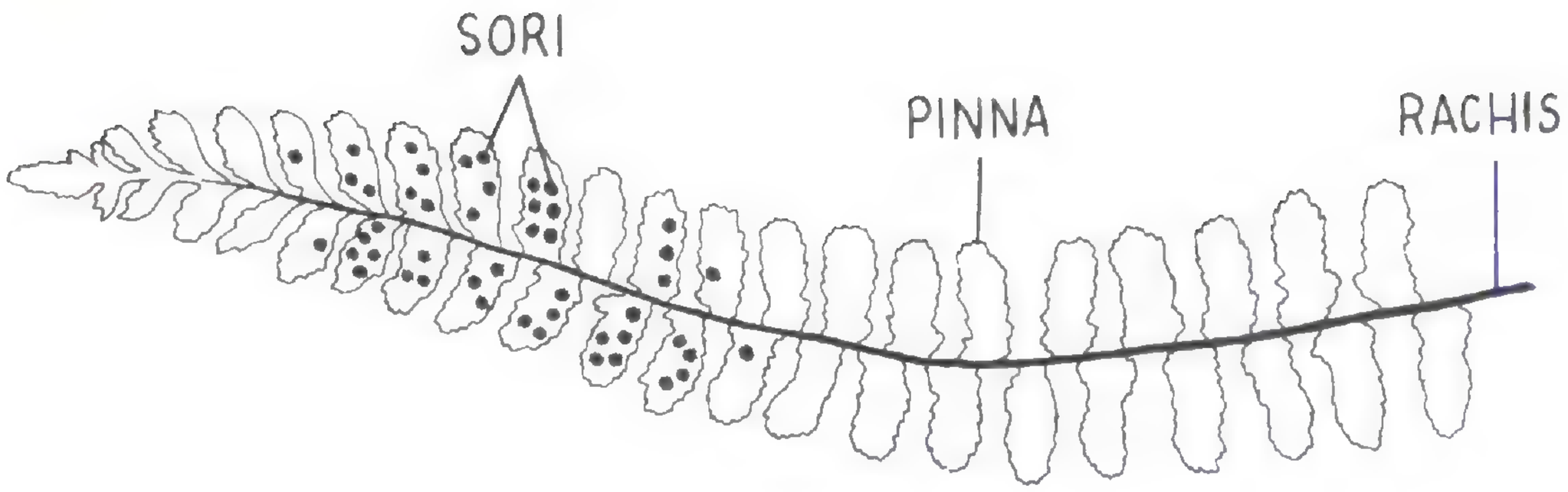


Figure 2. Typical fern frond with sori.

tures called *sori* (singular: *sorus*). A woman once called me about some little brown bugs on her fern plants. You guessed it! After just a little interrogation, her bugs turned out to be sori. She had been careful to pick off each one of these as they formed on the leaves. Sori are clusters of stalked *sporangia* containing *spores*. The sporangial groupings may or may not be covered by an umbrella-like *indusium*, a good taxonomic feature. The accompanying photograph shows a vertical section through a sorus. Some ferns produce their sori on special branches which are not leafy. Such sori usually lack an indusium.

The sporangium is an interesting device. It not only forms and contains the spores, it also disperses them. Dispersal is accomplished as a result of a gradual drying out of a special ring of thick walled cells called the *annulus*. The tension resulting from this causes the sporangium to rupture, quite vigorously casting out spores.

In reviewing the events of reproduction in ferns, the botanically well-known feature of alternation of generations should be discussed briefly. A simple way of describing this is that in reproduction, a diploid, spore-bearing plant alternates with a haploid, gamete-producing plant. The former is the dominant, vascular generation, the latter an inconspicuous, non-vascular phase. We could refer to this as the morphological expression of alternation of generations. The diploid fern plant has a normal number of chromosomes, whereas the haploid prothallium has but one-half the normal chromosome complement, a feat accomplished by the type of cell-division known as *reduction division* which usually precedes events relating to reproduction. (The other cell-division type relates to the

growth of an organism.) This represents the genetic expression of alternation of generations. For a graphic illustration of the foregoing, see figure 3.

The significance of this phenomenon is fundamentally difficult to assess. This is not only true for the botanist, but more so for the non-botanist. Alternation of generations assumes importance only when considered in an evolutionary context. Theoretical botanists look to two possible avenues along which such a process may have come. One theory postulates that the dominant, spore-bearing phase somehow interposed itself into the reproduction sequence of things. This is the Antithetic or Interpolation Theory. The second theory supposes that both phases—spore-bearing and gamete-producing—are essentially similar, the former having arisen from a stock of structurally less well differentiated plants whose vegetative and sexual phases were similar. This is the Homologous Theory. It is felt that further exposition of either theory rests in future fossil finds. Nature has given this alternation process some difficulties which are beyond the scope of this article.

It is interesting to note however, that the fern sporophyte lives independently of the prothallium that produced it, and that the latter dies soon after active sporophyte growth. In contrast to this, the sporophyte generation of mosses completes its life function while permanently attached to the haploid generation of the plant. In flowering plants, the gamete generation performs its function while attached to the diploid phase.

Concepts and insights like these do not come through to fully integrated human consciousness all at once. Years pass before perspectives are in correct proportion. So it is small wonder that even

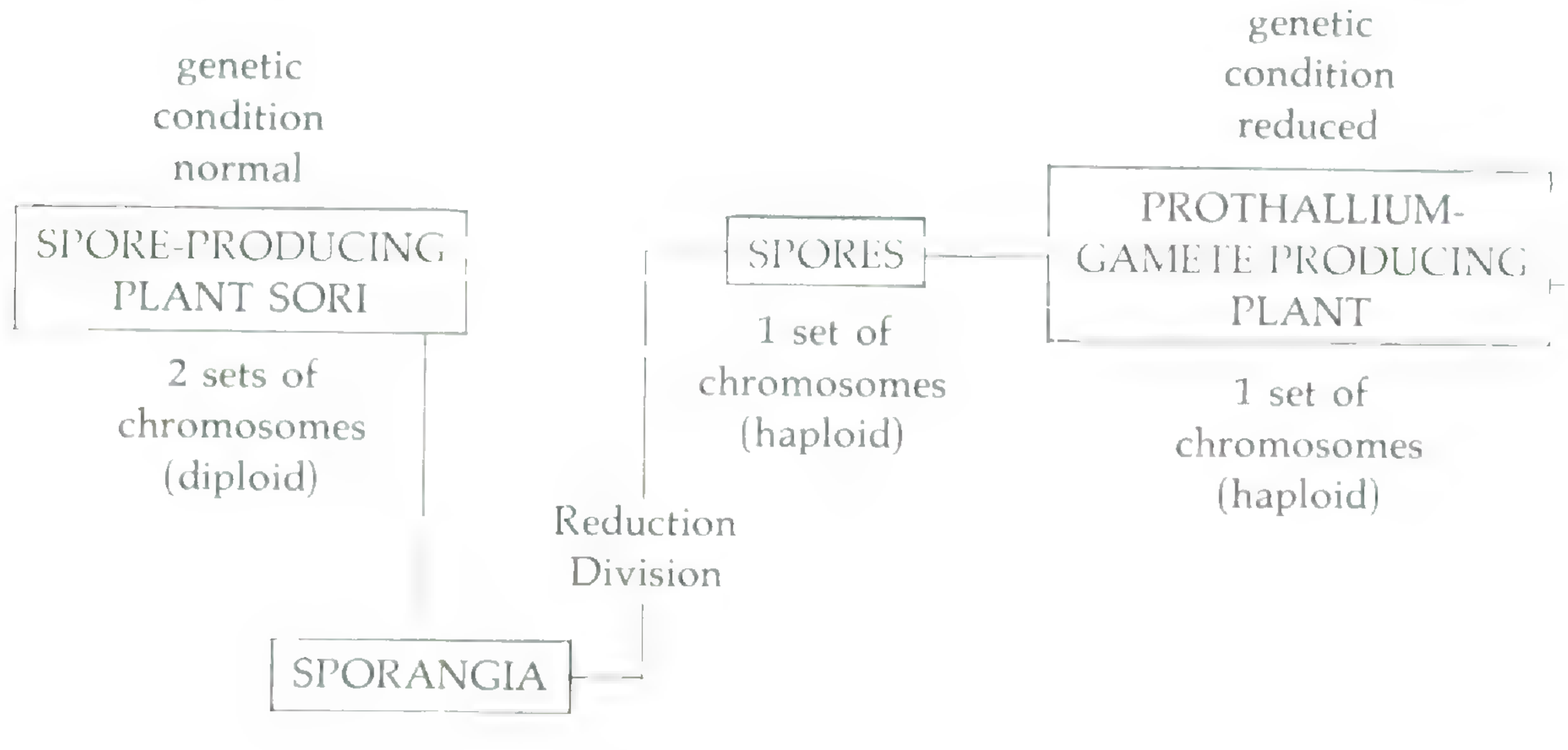


Figure 3. Alternation of generations. See text.

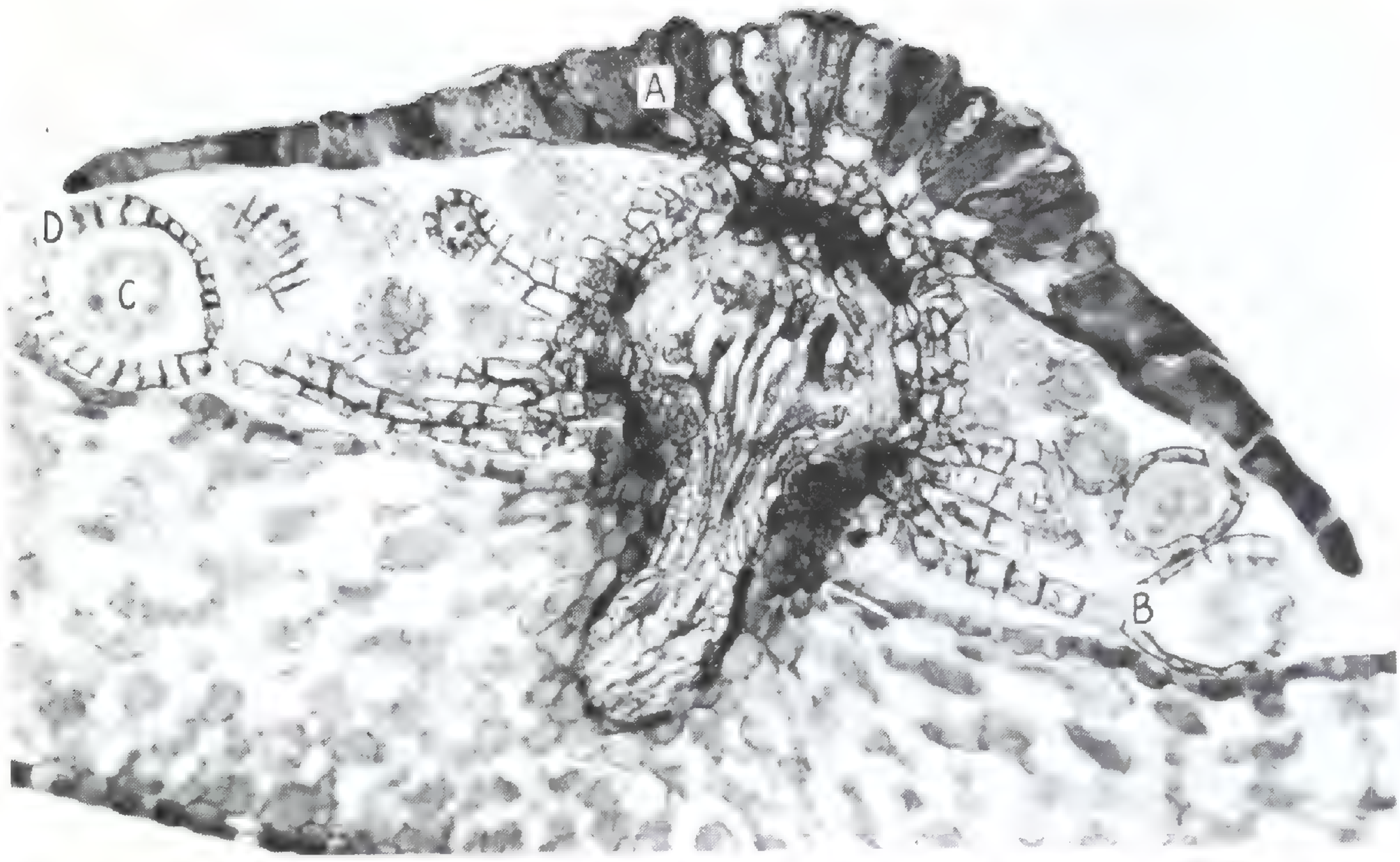
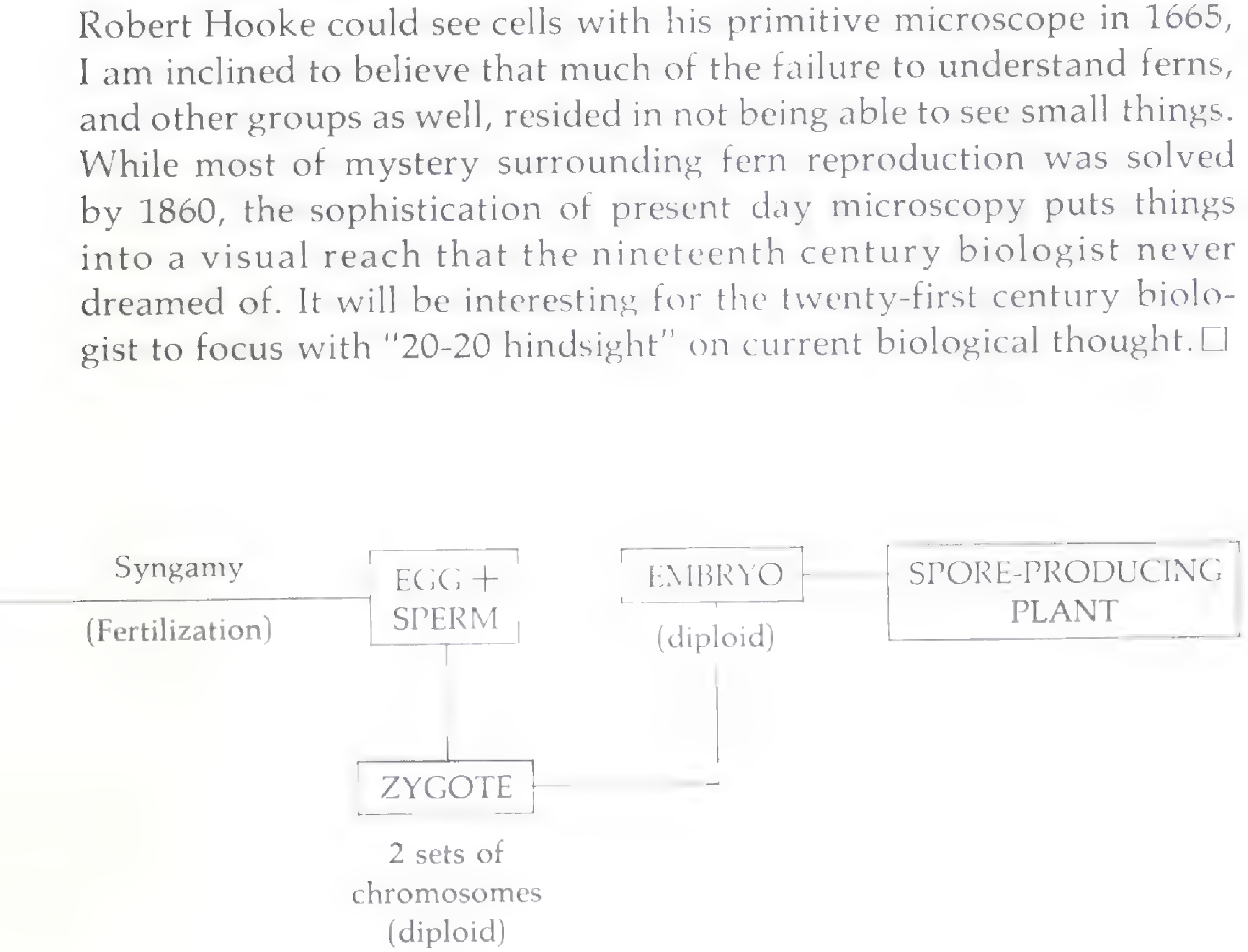


Figure 4. Greatly enlarged photo of vertical section through sorus of Holly Fern.
A—indusium; B—sporangium; C—Spores; D—annulus.

as late as 1840, ferns were considered to be sexless. Even though Robert Hooke could see cells with his primitive microscope in 1665, I am inclined to believe that much of the failure to understand ferns, and other groups as well, resided in not being able to see small things. While most of mystery surrounding fern reproduction was solved by 1860, the sophistication of present day microscopy puts things into a visual reach that the nineteenth century biologist never dreamed of. It will be interesting for the twenty-first century biologist to focus with "20-20 hindsight" on current biological thought. □



Fern Culture

Robert Dingwall

THERE ARE ABOUT 300 varieties of ferns found growing in the United States. Ferns are ideal for damp, low spots, shady areas under trees, and on north sides of buildings. There are few gardens that are without a suitable spot in which hardy ferns would flourish. While a few ferns will tolerate a certain amount of direct sun, there are none that require it.

Ferns make a fine background for many flowering plants. The deciduous types are especially valuable to fill the empty spots where spring bulbs have bloomed.

Ferns help to cool the ground and moisten the atmosphere, shading the plants beneath them like a parasol which is very helpful for young plants or for delicate flowering ones.

Spring or fall is the best time to plant or move ferns. Those with running rootstocks, however, will send up new fronds if transplanted in any season. Running rootstock types such as hay scented, bracken, and ostrich tend to overrun their sites so plant these only where you want a large mass effect.

Ferns may be purchased from a wildflower nursery or dug up in the woods where they grow naturally, provided you first secure permission from the landowner. In planting, most ferns with spreading roots do best if the roots are barely covered, while some central crown types like the crown exposed and others prefer the crown at the soil surface.

Careful preparation of the soil before planting is essential. Remember that ferns are woodland plants and in nature grow in a

spongy carpet of rotted humus made up of decayed leaves and wood that has accumulated over the years. They cannot stand a heavy soil. Do not use lime, as most dislike it. Dig the soil deeply and incorporate with it a liberal supply of organic material such as leaf mold, peat moss, or compost so that food and moisture are conserved.

Once ferns are established it is wise to mulch annually with organic humus, and wood ash, at 1/4 pound per square yard, as these materials contain all the main requirements for them. Do not use chemical fertilizers as they cause the plants to brown and in many cases, to die. If fertilizer is needed for a boost in growth, fish meal, or cotton seed meal applied in spring is sufficient.

Rock growing ferns are hard to establish on rocks but planted alongside the rock, they quickly spread over it. For sunny rocks the hay scented, Woodsia, ebony, spleenwort, bracken, and cliff-brake are good. The hay scented fern will thrive in the shade also. Also good around rocks are harts-tongue, royal, northern lady, maidenhair, and the evergreen and marginal wood ferns.

Claude Johnston

The Boston fern (*Nephrolepis bostoniensis* cv. Fluffy Ruffles) is an old favorite. This is the fern so often seen in barber shops.

Claude Johnston

The holly fern *(Cyrtomium falcatum)*, a smaller and more rugged variety than the Boston fern is an excellent house plant.

For large mass planting in the shaded area, the handsome cinnamon or the interrupted fern are ideal. The cinnamon fern has colorful fruiting fronds that resemble flower heads. The leathery fronds of the sword ferns are also eye-catching planted thickly under dense shade trees.

For dry, shady plants the Christmas fern is ideal and is evergreen. For boggy spots, try the marsh fern, sensitive fern, or the New York fern. The royal fern prefers full sunlight but will tolerate very wet conditions such as lake or pond borders. The popular hardy maidenhair is easy to establish in any well-drained area.

For limestone sites the walking fern spreads to a tangled mat over mossy rocks in the shade.

INDOOR PLANTING

Ferns of the tropics and subtropics are the greenhouse ferns of temperate zones and include a number of kinds suitable as house plants. To cultivate them successfully it is desirable to imitate the

environment in which they grow naturally and to provide the moist, humid, sunless, but light conditions so essential to their well being.

Household climates do not maintain as high humidity as conditions in a greenhouse. Some ferns, notably the sword fern *(Nephrolepis exaltata)*, the holly fern *(Cyrtomium falcatum)*, and the squirrel's foot fern *(Davallia bullata)* will succeed as house ferns.

Soil for these ferns should be rich organic soil with good drainage. Some people like to mix some charcoal in the soil mix to keep it "sweet." Ferns will need to be repotted from time to time. In the greenhouse this can be done at any season of the year although spring is best.

The temperature in the greenhouse is important. A night temperature of 55° is best with a 10°-15° rise for the day temperature. Avoid high temperatures as these slow growth and in some cases are detrimental to good growth.

Propagation of ferns is often done by division when moving or repotting. They are also grown from spores (they do not produce seed as in higher plants). The tiny, dust-like spores are clustered on the backs or edges of the fronds (leaves). Brush these off gently on paper and let dry for a week or two, then shake onto a pot of moist leaf mold and sand. Set the pot in a saucer of water and cover with a piece of glass to retain moisture. Young plants will be ready to transplant in four to six months.

Never allow the soil in which the ferns are growing to become dry, and also never let it become water-logged. Keep the ferns' leaves clean. This is best done by syringing them with clean water on all bright days.

Thrips and red spider can be troublesome, especially in a dry atmosphere. The two can be kept in check by frequent syringings of water, being sure to hit the underside of the fronds.

Monthly feedings of diluted manure tea or liquid fish emulsion will keep all ferns healthy and vigorous for years. □

Mr. Ward's Portable Greenhouse

Duncan M. Porter
Illustrated by Marjorie Richardson

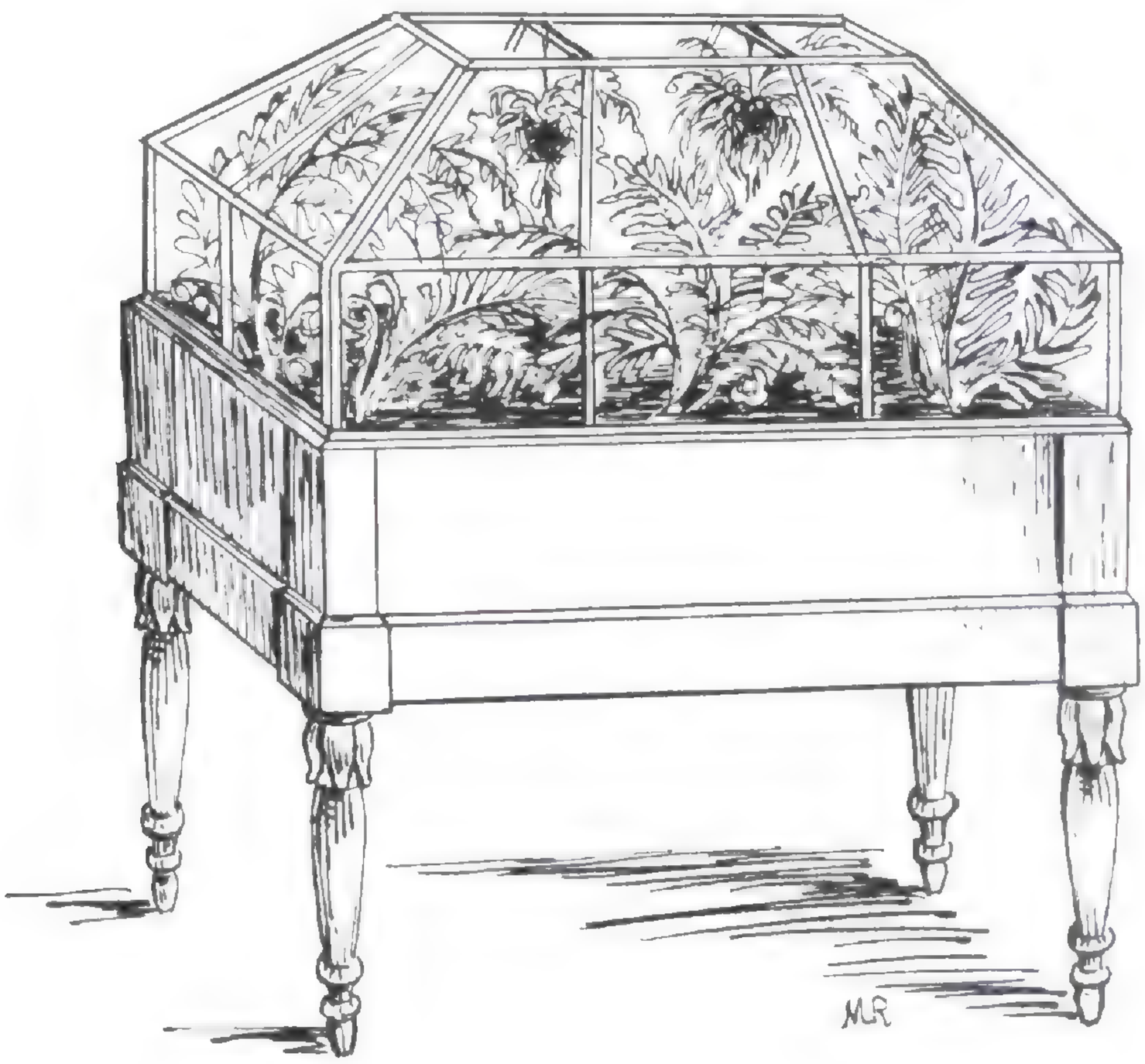
THE ATMOSPHERE OF William IV's London during the 1830's may be likened to that of St. Louis during the 1920's. In both cities increasing industrialization, with the widespread burning of soft coal, filled the air with smoke and soot and killed great numbers of plants, both wild and ornamental. In St. Louis this situation led the Missouri Botanical Garden to purchase a tract of land far out in the clearer skies of the countryside near Gray Summit, then planned to become the Garden's new home. When pollution from soft coal was brought under control, the abandonment of the city proved unnecessary. In London the increasing atmospheric effluents spewed by the Industrial Revolution led, among other things (such as epidemic rates of respiratory diseases), to the invention and widespread use of the Wardian Case.

Nathaniel Bagshaw Ward (1791-1868) was a London surgeon who was also an ardent amateur botanist. In 1830 he happened to notice that several seedlings had begun to grow in some moist soil in the bottom of a loosely-capped bottle into which he had placed a moth chrysalis the previous summer. The seedlings proved to be *Poa annua* (annual blue grass) and *Dryopteris filix-mas* (male fern). Ward placed the bottle on his window-edge, and the plants continued to thrive without the addition of fresh water—for at least nineteen years.

His curiosity aroused by the seedlings, Ward put a native *Hymenophyllum* (filmy-fern) into another bottle and found that

it too survived untended. These initial observations led Ward to undertake a series of experiments using both ferns and flowering plants. He had constructed a number of small greenhouses, about the size of breadboxes, sealed with putty, and watered the plants within them every five or six weeks. These small greenhouses, or "fern-boxes" as Ward called them, proved admirably adapted to the growing of ferns and other plants difficult to cultivate in the open air.

The principle of Ward's invention is quite simple. Plants may be placed in soil inside a glass box and watered; then the box is closed. The box need not be airtight, only tight enough to keep most of the moisture from escaping. When the sun shines through the glass, evaporation and transpiration serve to saturate the air inside the box with water vapor, which condenses on the glass and runs back down into the soil. The Wardian Case is essentially a closed system. So long as there is sufficient light for photosynthesis and the temperature does not get too hot or too cold, plants may exist in it indefinitely, although some additional water must be added from time to time.



Wardian Case filled with ferns. After an illustration in *An Analysis of the British Ferns and Their Allies*, by G. W. Francis (second edition, 1842).

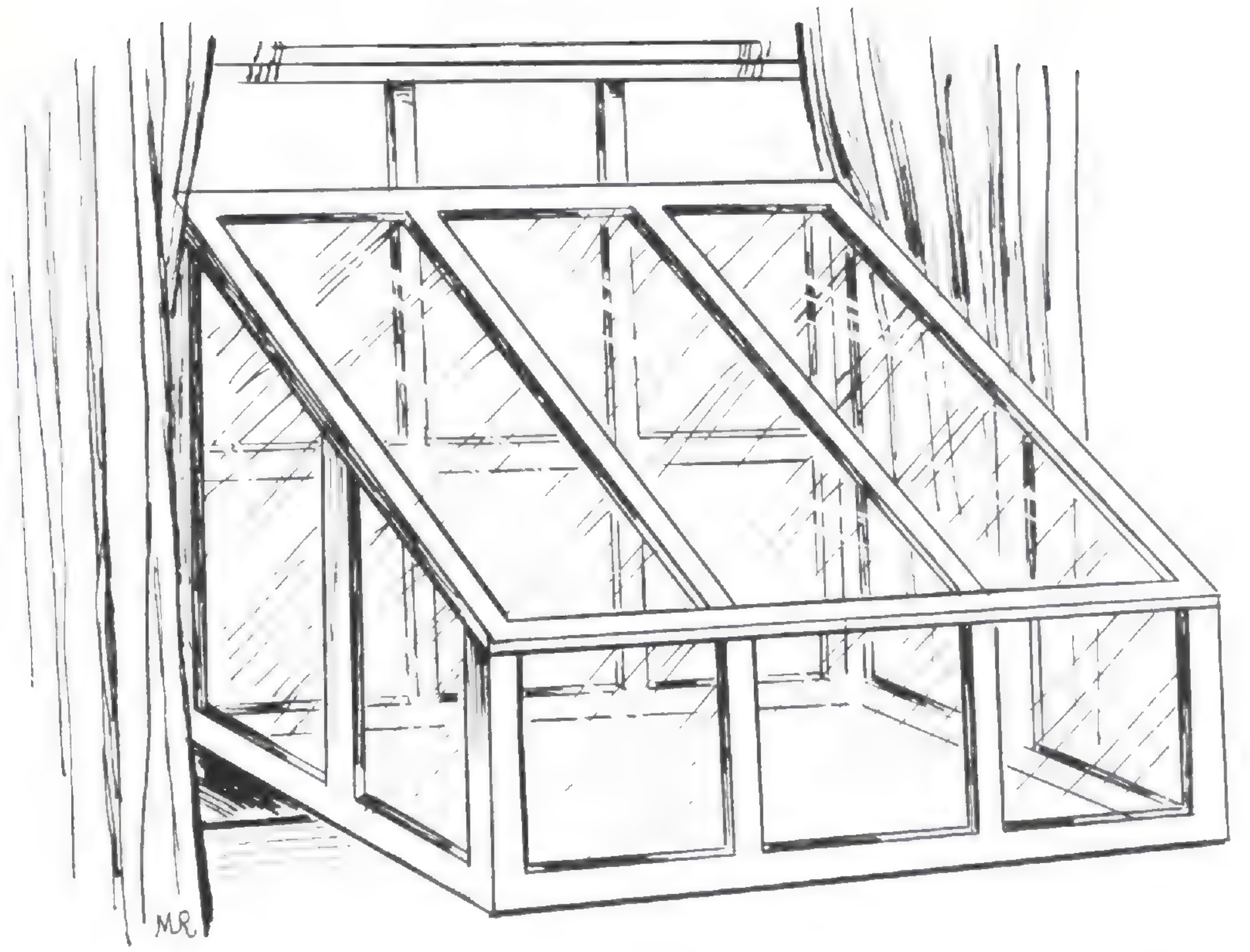
When Ward was pursuaded to make his invention, later advertised as "Wardian Cases of Ferns or Ward's Portable Greenhouses" known to the public in the mid-1830's, its potential was immediately recognized, by scientist and layman alike. Nathaniel Ward was not the first to grow plants under glass. Others had done so, some utilizing the very techniques that Ward had discovered independently. The popularity of the Wardian Case was the result of several factors, particularly air pollution and the curious tastes of the English middle class.

The filthy smoke-filled air of metropolitan areas allowed few of the usual ornamental plants to survive outside, let alone the frail exotics. Add to this the sputtering gas-jets inside, and one wonders how even potted plants in the parlour managed to exist. True, the rich had their full-sized greenhouses. Mass-produced sheet-glass became available in England in the 1830's, but high excise duties on glass prior to 1845 severely limited greenhouse construction.

About the same time that Ward was perfecting his cases, a new phenomenon burst upon the British public: pteridomania. The rise, spread, and decline of this phenomenon have been ably outlined by David Elliston Allen in his interesting little book *The Victorian Fern Craze* (Hutchinson, London. 1969). In essence, pteridomania was a continuation of the cabinet of curiosities popular in the previous century. Now, living ferns were substituted for fossils, shells, or pressed seaweeds. Since it was impossible to grow ferns exposed to a city's air, what better place to grow them than in a Wardian Case?

The Wardian Case provided the vehicle by which the pteridomaniacal craze spread through early-Victorian England. This utilitarian object provided the means to grow ferns in places with air too foul or too cold to grow them elsewhere. Most middle class households were unable to buy the glass necessary for a full-sized greenhouse, but few could not afford a Wardian Case. For those who could not, bell-jars or the jars of druggists or confectioners provided inexpensive substitutes. Practically anyone could become a fern-fancier.

In the beginning, simple Wardian Cases were used by the affluent and fashionable to display the latest arrivals from the tropics. As time went by, the cases became more and more elabor-



The window greenhouse, a 20th-century equivalent of the Wardian Case.

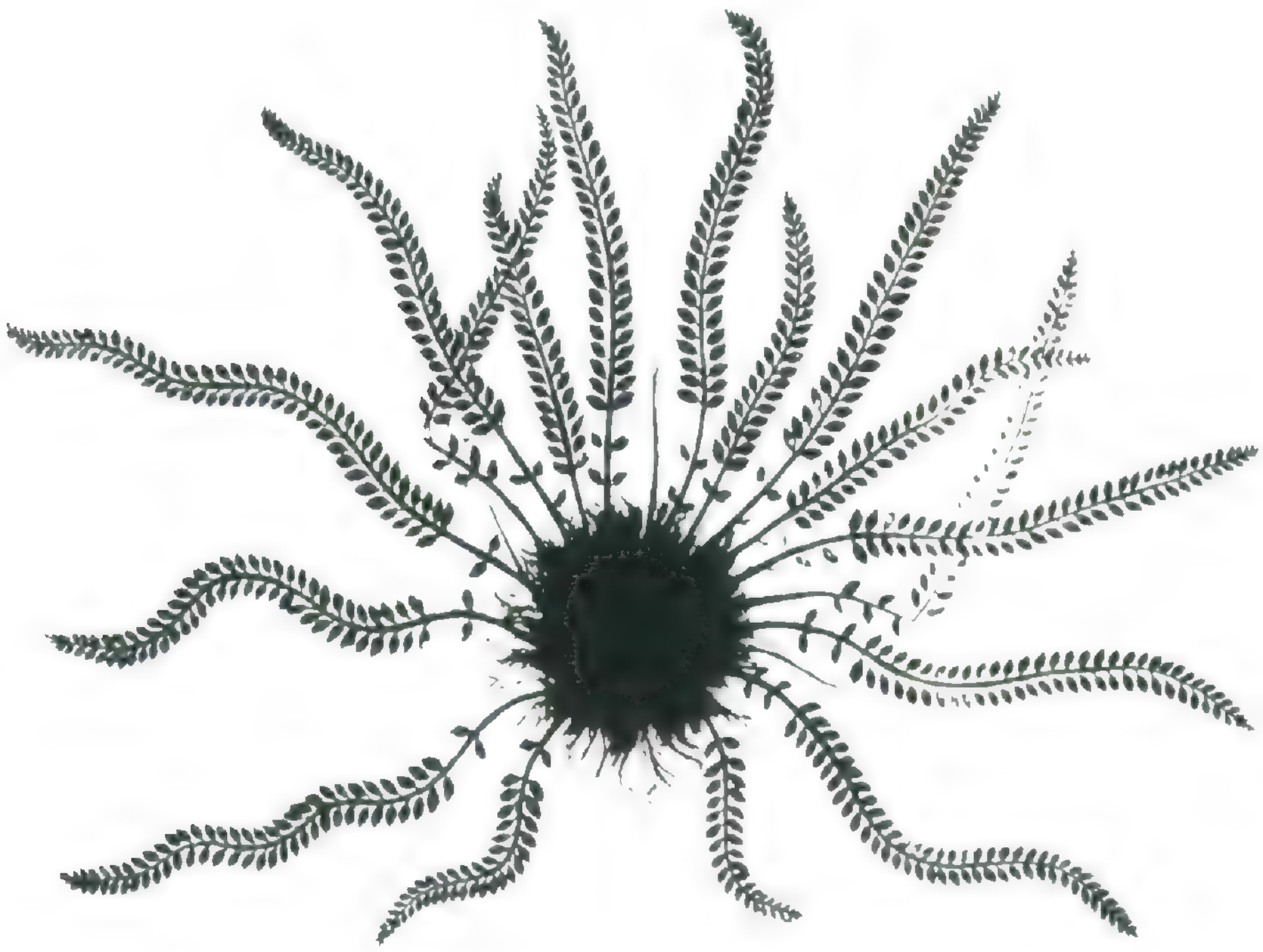
ate, covered with all sorts of Victorian gee-gaws, and the fern craze eventually deteriorated into the hoarding of monstrosities, many of which we would find less interesting than objectionable. Although today's terrarium and aquarium are the direct descendents of Wardian Cases, few are as elaborate as those of late-Victorian times.

While the Wardian Case was evolving into a parlour decoration, it was also being put to a less sophisticated but far more utilitarian purpose. As early as 1832, Ward had sent several of his sealed cases from London to Australia. The plants arrived in good condition, as did those sent back to England on the eight-month return voyage. Thus began a new era in plant exploration and introduction.

Hitherto, it had been necessary to carefully pack seedlings and cuttings in moss, and to expend precious fresh water on them while in transit. More often than not, available fresh water was drunk by the crew, and few plants survived the trip. With the development of the Wardian Case, seedlings and cuttings could be placed on the deck of a ship to receive sunlight and still not be subject to the viscissitudes of salt spray and the lack of fresh water. Live plants could now be transported from one part of the world to another with relative ease.

The first plant explorer to make use of the Wardian Case was the great Robert Fortune, who introduced many Asian exotics into the western world through the Royal Horticultural Society. To Fortune and the Wardian Case we owe the introduction of tea from China to India, which took place in 1848. Besides the countless exotic ornamentals, such as Fortune's Himalayan rhododendrons, that now enhance our gardens, Wardian Cases brought *Cinchona* (the quinine tree) from South America to Java and India, rubber trees to Java and Malaya from South America, coffee from Africa to the New World, and bananas from South-east Asia to the rest of the tropics.

Captain Bligh of *Bounty* fame would have had a much better time of it had he had Wardian Cases in which to transport his precious breadfruit seedlings from the East to the West Indies. But the annals of the sea would have been poorer for it—and who would have ever heard of Pitcairn's Island? □



Maidenhair spleenwort (*Asplenium Trichomanes L.*). Illustration is from the facsimile reprint of the *Codex Diocurides, Anicicia Juliana*.

FERN LORE

Erna R. Eisendrath

"I WONDER WHY Ferns are such a nameless sort of things, not nearly so livable and lovable as flowers," said Flower Hat, as she leaned against a sloping rock . . ." Her companion, Mabel Osgood Wright, who reported the conversation in *Flowers and Ferns in their Haunts*, in 1901, was hard put to find an answer. Perhaps, she suggested, it is because "the Fern does not appeal directly to insect or man through a specialized color, or perfume." Perhaps, I add, it is because ferns have not played a large role in man's economy, as food, drug, or otherwise useful plant. Whatever the reason, as Mrs. Wright acknowledged, ferns had in 1901 "scanty literature and few gracious names." There are few more of either to-day, although mention of ferns can be dug out of our most ancient botanical literature, and the lore that has built up around them, little as it may be, can be found persisting in various sorts of ways.

One of these, for instance, is in fern names, both popular and botanical. *Asplenium* can be traced back to an early belief that in those parts of the Island of Crete where the "spleenwort" grew wild, flocks that ate of the fern were spleenless, whereas in those areas where the fern did not grow, the animals' interiors were quite normal! Again, *Adiantum* comes from a Greek word *(adiantos)* that means "unmoistened," and goes back to a fact noted by Theophrastus in the 4th century B.C. "In 'wet-proof' the leaf does not even get wet when it is watered, nor does it catch the dew because the dew does not rest on it; whence its name." In another instance, the specific epithet applied to our native "southern maidenhair," the *Adiantum capillus-veneris*, (see cover illustration and article, page 3) refers

back to the myth that when Venus rose from the sea her hair, like this "maidenhair fern," appeared to be dry! *Botrychium lunaria* is distinguished from the other "grape ferns" by the specific epithet describing the shape of the leaflets on its fronds, a sign, according to the "Doctrine of Signatures," that the plant would be useful in the treatment of diseases of a periodic character, themselves under the influence of the moon. The common name, "moonwort," often applied to this fern has, therefore, an obvious derivation, but other common names are not so easily explained. The American fern authority, Willard Clute, reported that it was once known as the "blasting-root" because the strongest locks were thought to fall open in its presence; Culpeper, almost two hundred years ago, connected it with "fetlocks," thus leaving Clute's lore open to suspicion! Culpeper wrote:

> Alchymists say, that this herb is peculiarly useful to them in making silver; and it is reported that whatever horse casually treads upon this herb will lose his shoes; it is also said to have the virtue of unlocking their fetlocks and causing them to fall off; but whether these reports be fabulous or true, it is well known to the country people by the name of Unshoe-Horse.

As either "blasting-root" or "unshoe-horse," *Botrychium lunaria* is credited with miraculous powers closely related etymologically if in no other way. Equal powers must have been thought inherent in its relatives, *Botrychium virginianum*, the "rattlesnake fern," and *Ophioglossum vulgatum*, the "adder's tongue fern," but one is left wondering about the relation of ferns in general to the reptiles. Pliny, long ago, wrote:

> Fern-leaves kill bugs, and serpents will never harbor among them: hence it is a good plan to strew them in places where the presence of these reptiles is suspected.

But Mr. Clute felt quite differently about them, saying:

> Just as the average individual imagines every species of snake to possess fangs and venom and regards it as something like a duty to kill it, so does he consider ferns to be the natural protectors of these creatures and to be shunned accordingly.

However the reptiles may react to these fern genera, believers in the "Doctrine of Signatures" have recognized over the centuries that the resemblance of their fertile fronds to the hindmost part of the rattle-snake furnishes sound evidence of their efficacy in the treatment of snake-bite.

By the same token, the small and difficult-to-see fern spore is probably the basis of the once wide-spread belief that the possession of fern spores, collected under very strictly observed conditions, would render their bearer invisible. These conditions were similar throughout Europe. The spores could be collected only on St. John's Eve, the shortest night in the year, and only then if the collector went after them bare-foot, in his shirt, *and* in a religious state of mind. If the collector's preparations and timing were correct he would be rewarded by seeing the fern produce a small blue flower, as well as by achieving his original purpose. Something was obviously wrong with the preparations of the character in Ben Johnson's *The New Inne*, who bemoans the fact that "I had no medicine, sir, to walk invisible, No fern-seed in my pocket." Falstaff's companion, Gadshill in *Henry IV*, fared better, and was able to report to the Chamberlain, "We have the receipt for fern-seed, we walk invisible;" but, if you remember your Shakespeare, you'll know that the Chamberlain was skeptical. "Nay, I rather think," he replied "You are more beholden to the night than to fern-seed, for your walking invisible."

Clute reports another effect of "fern seed," related again to optics:

> In Russia fern seed was supposed to confer second sight. It is related that a man went out to search for his cattle, when some fern seed fell into his shoes. He at once knew (not only) where his cattle were, but discovered some buried treasure besides. Going home for a shovel with which to dig it up, his wife unfortunately induced him to change his shoes, when the fern seed fell out and was lost and with it went all knowledge of the treasure.

The fern usually associated with this business of invisibility is the common "bracken," *Pteris aquilina*, which, unlike most ferns, grows in full sunlight, often in poor soil. Its popular name probably

comes from the German *Brachie*, meaning uncultivated ground, referring to the fact that old fields, not recently plowed, are often covered with "bracken," which takes over quickly, particularly after burning. This may account for a legend that associates the "bracken" with fire, a belief that burning over the area in which it grew would induce rain. The Earl of Pembroke and Montgomery, responsible for the comfort of Charles I during a 17th century royal tour, wrote the High Sheriff of Staffordshire requesting that no such burning be permitted during His Majesty's visit to that area, as the King was "desirous that the country and himself . . . enjoy fair weather as long as he remains in those parts."

The "bracken" stem is also reported to bear religious symbols that are variously interpreted. In cross-section, the Scots are said to have seen the pattern of the fern's vascular bundles as representing an impression of the devil's foot; elsewhere, on the other hand, the same pattern has been related to the Greek letter "X", the initial of Christ, and therefore very frightening to witches. Surely more frightening still is the Irish interpretation of the vascular pattern as observed in different sections of the stem: in one was observed the letter "G," in the next, "O," and in the third, "D." Accordingly, the "bracken" is sometimes referred to in Ireland as the "Fern of God."

Ferns as a group do not, however, stand high in the hierarchy of Scriptural plant lore. Ferns *are* ferns, indeed, by definition plants of a lower order than those that produce flowers, because the fern ancestors included among the plants that made up the straw in the stable of the Nativity did not, like the other plants, bloom in honor of the event and were, therefore, condemned forever after to remain flowerless.

Another religious connotation is found in connection with the genus *Polypodium*, of which it is said that "the grey powdery Lichen that gathers about (its) roots . . . came first from the Blessed Mother's milk having fallen to earth, and that from the stained soil arose this fern."*

With its beginnings so literally sublime, I can't resist telling you of a use for this fern so very lowly as to verge on the ridiculous; since it was suggested by no less an authority than Izaak Walton I

*Dowling, A.E.D.R.; *The Flora of the Sacred Nativity*, London, 1900.

feel justified in doing so. If one's worms, Walton suggests in *The Compleat Angler,* are anointed with a drop or two of oil from the "polypody of the oak" they (the worms!) will be given so tempting a smell that "the fish will fare the worse and you the better for it.

There is no space for me to dwell further on the uses that have been made of ferns, though many are recorded. Well worth our limited space, however, is a legend often traced to a fern, a legend that has nothing to do with its usefulness and has, indeed, in the opinion of some authorities, nothing to do with ferns. However the "Vegetable Lamb of Tartary" was for so many years always associated with the fern that it is the most important of all "fern lore." The earliest written report on this curious creature is thought to have appeared in a Latin version of the Talmud, dating from 436 A.D. According to this version there grew in Tartary

> a zoophyte or plant-animal, in form of a lamb, from whose navel grew a stem by which it was fixed, attached like a gourd to the soil below the surface of the ground. According to the length of this stem, it was able to devour the herbage that grew around it, just as does an animal eat all that grows within reach of the radius of its tether.*

Reports concerning the same natural marvel are contained in the work of "Sir John Mandeville," in the latter half of the 14th century. Whoever it was who wrote under this pseudonym tells of gourd-like fruits which "when thei ben rype men kutten hem ato, and men finden with inne a lytylle Best . . . as though it were a lytylle lomb." In the early 17th century, Parkinson thought the "Vegetable Lamb" so great a wonder as to include it among the inhabitants of the Garden of Eden, illustrated in the handsome frontispiece of his *Paradisi in Sole;* he very possibly thought, however, that Eden was the only place it ever grew, since I can find no mention of it in his text!

Later in the century the great naturalist, Sir Hans Sloane, undertook to lay the rumour that the "Vegetable Lamb" had ever grown any place at all. Sir Hans exhibited before the Royal Society, in 1698,

*Lee, Henry; *The Vegetable Lamb of Tartary,* London, 1887.

a bit of fern rhizome that did, indeed, look something like an animal, but not nearly so much as the specimen shown to the same august body a quarter century later by a Dr. Breyn of Danzig. Both men argued that the rumours that had spread from Western Asia and been a subject of discussion by learned men during many centuries were based upon the chaffy scales that often cover the lower parts of the fern plant so thickly as actually to look like wool; when such "wooly" bits of the plant were "doctored up" a bit they could readily be made to resemble little animals. Sir Hans and Dr. Breyn sounded the death knell of the ancient rumour for the learned world, but its popularity, persists in some parts of the world even to-day. In an article that appeared in this publication in 1955, when Dr. Alice Tryon was on the Garden staff, she identified the source of the "Vegetable Lamb" as *Cibotium Barometz*, a fern common in parts of Formosa; in Russian, "Barometz" means "little lamb," confirming Dr. Tryon's statement that the "country folk" of the area "gather the stems (of this plant), add the essential parts and fix the face, preparing the lambs for the city market. The illustration Dr. Tryon uses is strangely reminiscent of the creature pictured so long ago by Parkinson!

Certainly the ferns have not contributed greatly to the mass of plant lore that man has accumulated over the centuries; but they played a role in this area of Victorian taste as in the others discussed and exhibited at the Garden at this time. In the several popular books of the period that are concerned with "the language and sentiment of flowers" we find ferns used to symbolize sincerity. The reasons for this should, perhaps, be obvious; if they are not, let me explain by quoting from Catherine H. Waterman's *Flora's Lexicon* of 1855.

> Fern often affords an agreeable seat to lovers; its ashes are used in the manufacture of glasses for the convivial party; and all the world knows that love and wine make men sincere. □

Etymological Glossary

Term	*From*	*Original Sense*
Annulus	Latin	= ring
Antheridium	Greek	anthos = flower
Archegonium	Greek	arche = old gonium = parent
Diploid	Greek	diploos = double
Frond	Latin	frons = leaf
Gamete	Greek	gamete = wife gametes = husband
Gametophyte	Greek	gameto + phyte = plant
Haploid	Greek	haploos = single
Indusium	Latin	= tunic
Pinna	Latin	feather
Prothallus Prothallium	Greek	pro = first thallus = twig, bloom, shoot
Protonema	Greek	Proto = first nema = thread
Rachis	Greek	rhachis = spine
Rhizoid	Greek	rhiza = root oid = form, like
Sorus	Greek	Soros = heap, group
Sperm	Greek	= seed, sow
Sporangium	Greek	angeion = vessel
Spore	Greek	spora = seed
Sporophyte	Greek	Sporo + phyte
Syngamy	Greek	syn = with gamos = marriage
Zygote	Greek	zygotos = yoked

An Introduction to the Ferns of the Arboretum

Marshall R. Crosby
(Author illustrations)

Over sixty kinds of ferns and fern allies are known to occur in Missouri. Only fourteen of these are definitely known from the Garden's Arboretum at Gray Summit. However, these fourteen provide a good introduction to Missouri's ferns, since a good diversity of forms are represented.

This introduction provides a means of identifying the ferns and their allies of the Arboretum by means of a botanical key combined with pictures (not all drawn to the same scale) showing important features of each fern. The key consists of numbered pairs of contrasting statements describing features of the plants. To use the key, both statements in a pair are read, and the one describing the plant at hand is followed. After following one or more such statements, one reaches a pair of silhouette sketches representing two ferns. These are distinguished by referring to the brief statements describing characteristic features of each. Arrows point out these features as depicted in the silhouettes.

Technical terms describing ferns have been kept to a minimum in this introduction. Briefly, the fern leaf is called a frond. The frond may be simple or compound—divided into leaflets (called pinnae). The pinnae may in turn be compound. The stalk below the first pinnae of the frond is the stipe, and the stalk above the first pinnae is the rachis. The sporangia are the organs which produce the spores by which the ferns reproduce. Sporangia are either large

and globular or almost microscopic and flattened. Ferns with almost microscopic sporangia have them clustered together into sori (singular, sorus) which are easily visible to the naked eye. A delicate piece of tissue called the indusium (plural, indusia) covers the sorus, at least when it is young. These and other features of ferns are discussed in the article "The Truth about Ferns" by Ken Peck on page 6 of this issue of the Bulletin. (See also glossary on page 27.)

The two fern allies treated here do not resemble typical fern plants and should not be mistaken for them. They are called fern allies because their life cycle resembles that of the true ferns.

Ferns

1. Sporangia large, yellowish, borne on a separate portion of the frond.

Limestone Adder's Tongue Fern *(Ophioglossum engelmannii).*

The sterile portion of the frond is entire and elliptical, and the fertile portion is erect and unbranched.

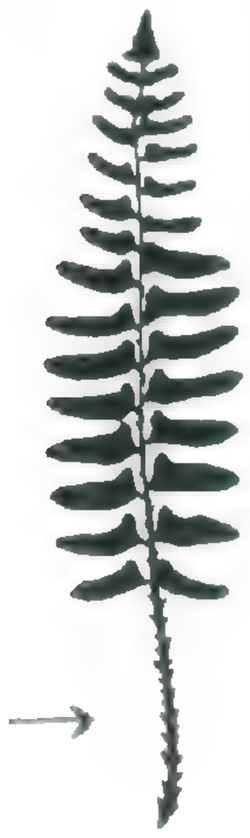
This fern is found on the numerous glades at the Arboretum.

Grape Fern *(Botrychium dissectum* var. *obliquum).*

The sterile portion of the frond is compound, and the fertile portion is erect and branched.

The Grape Fern is not uncommon where rich, moist woods meet the many meadows at the Arboretum. The Cut-Leaved Grape Fern *(Botrychium dissectum* var. *dissectum)* also occurs at the Arboretum, often growing together with the Grape Fern. It is distinguished by its very finely divided sterile portion of the frond.

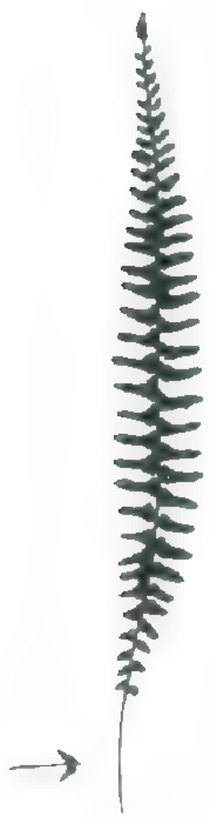
1. Sporangia small, clustered into sori on the backs of the green pinnae of the frond.
   2. Fronds with all the pinnae simple.



Christmas Fern *(Polystichum acrostichoides).*

The stipe and rachis are covered with numerous light brown scales.

This fern and the next are very common in the woods at the Arboretum. The sporangia are on the upper pinnae of the frond. Usually there are so many that they cover the entire surface, and the circular indusia appear to be wading in a sea of sporangia.

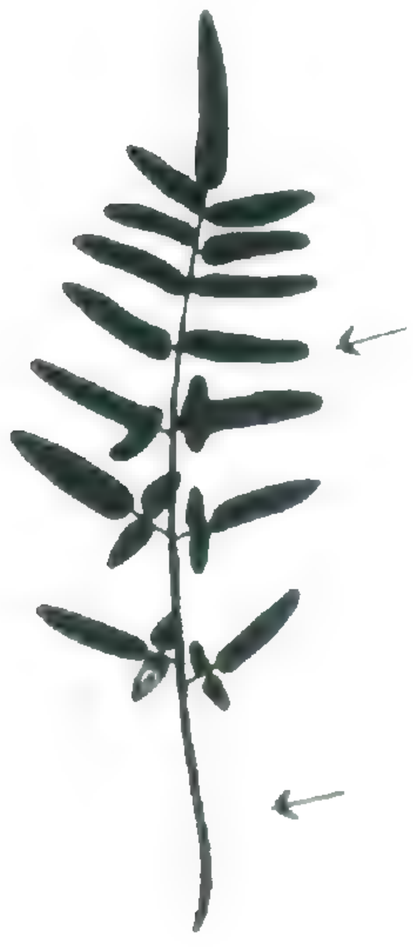


Ebony Spleenwort *(Asplenium platyneuron).*

The stipe and rachis lack scales.

The sporangia of this fern are in elongate sori on the backs of the pinnae. A flap-like indusium covers the sori when young, but as they mature the indusium is pushed back, and the sporangia cover most of the surface of the pinnae.

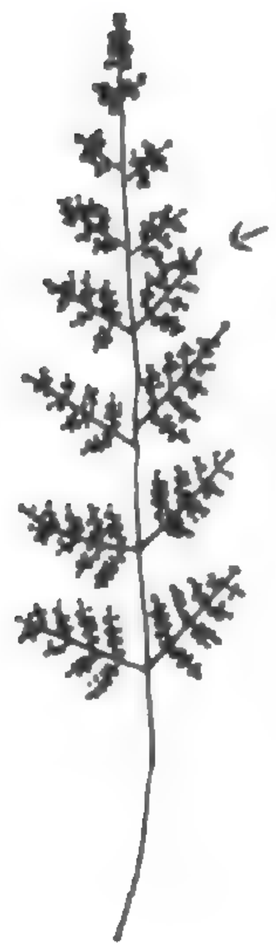
2. Fronds with at least some pinnae compound.
   3. Margins of the pinnae reflexed over the sporangia.



Purple-Stemmed Cliffbrake *(Pellaea atropurpurea).*

The pinnae are smooth and more than 1/4 inch broad.

The sporangia of Cliffbrakes occur near the margins of the pinnae and form a continuous sorus. The sorus lacks an indusium but is covered by the reflexed margin of the pinna. The Smooth Cliffbrake *(Pellaea glabella)* also occurs at the Arboretum. It has a smooth stipe, while the stipe of the Purple Cliffbrake has scales and hairs.



Slender Lipfern *(Cheilanthes feei)*.

The pinnae are densely wooly and less than 1/8 inch broad.

This tiny fern shares many general features with the Cliffbrakes—it even occurs together with them on limestone cliffs. Its small size and very hairy and narrow pinnae easily separate it from them.

3. Margins of the pinnae not reflexed over the sporangia.

Blunt-Lobed Woodsia *(Woodsia obtusa)*

The stipe and rachis are scaley.

This Woodsia and the Fragile Fern are similar in overall appearance. The scaley stipe and rachis of the Woodsia easily distinguish it from the Fragile Fern, however. The Blunt-Lobed Woodsia is common at the Arboretum in rocky woods.

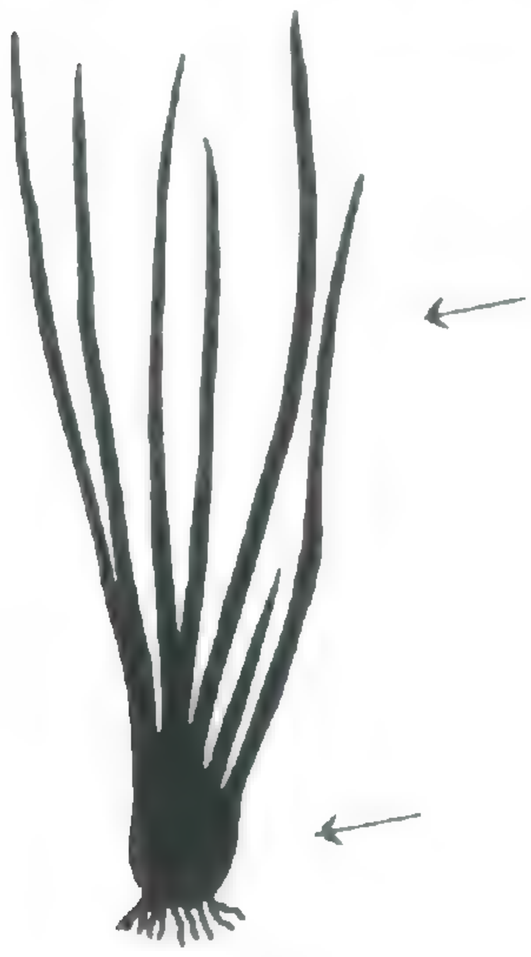
Fragile Fern *(Cystopteris fragilis)*.

The stipe and rachis are smooth.

The Fragile Fern's close relative the bulblets Fern *(Cystopteris bulbifera)* also grows at the Arboretum. It is similar to the Fragile Fern, but its fronds are usually longer and more slender, and it produces bulblets on the undersides of the fronds. The bulblets fall off, germinate, and grow into plants.

Fern Allies

1. Leaves long, grass-like, emerging from the bulb-like stem.



Butler's Quillwort *(Isoetes butleri)*

This very unfern-like plant is typical of the limestone glades at the Arboretum. It might easily be mistaken for Wild Onion or a sedge. Internally the leaves are partitioned into four air-chambers which run the length of the leaf. Each chamber is interrupted along its length by cross-partitions giving the leaf a slightly jointed look.

1. Leaves minute, forming notched rings at the nodes of the tall, jointed stem.

Rough Horsetail *(Equisetum hyamale)*

Found along the flood-plain of the Meramec River at the Arboretum, where it forms extensive stands on the sandy shores. The Field Horsetail *(Equisetum arvense)* occurs at the Arboretum in similar situations. This species has whorls of slender branches arising at the nodes, while the Rough Horsetail is unbranched at the nodes or rarely has a few branches at scattered nodes.

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Visit Your Missouri Botanical (Shaw's) Garden

The Missouri Botanical Garden's main entrance is at Tower Grove and Flora Place. The Garden is served by both the Sarah (No. 42) and the Southampton (No. 80) city bus lines.

The Missouri Botanical Garden Arboretum—1600 acres—established at Gray Summit, Missouri, in 1926, is open to the public.

The Garden—70 acres—is open every day except Christmas and New Year's. For the main entrance, grounds, Climatron, display greenhouses, and Floral Display House:

May 1 through October 31 . . . . 9:00 a.m. to 6:00 p.m.
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For Tower Grove House:

May 1 through October 31 . . . . 9:00 a.m. to 5:00 p.m.
November 1 through April 30 10:00 a.m. to 4:00 p.m.

The Display House presents four major shows: November, Chrysanthemums; December, Poinsettias; February, Orchids; April, Spring Flower Show. During the year other shows, competitions, and festivals are sponsored by various garden clubs and flower societies.

Courses in botany and horticulture for adults are conducted by the Garden staff. Children's nature classes are provided free on Saturdays from mid-September to early June. The Pitzman Nature Program is held for children during the summer. The Garden is world famous for its scientific research program. The scientists of the Garden hold teaching appointments on the staff of Washington University.

The Missouri Botanical Garden was established for the public's benefit in 1859 by Henry Shaw. The Garden, a non-profit institution, relies for support solely upon contributions from the public, the Arts and Education Council, and income from the Shaw estate. The Garden receives no city or state tax support.

Support your Garden and take part in Garden activities through the Friends of the Garden. Information may be obtained from the Main Gate or by mail or phone (865-0440).

MISSOURI BOTANICAL GARDEN

BULLETIN

VOLUME LIX NUMBER 3

MAY-JUNE 1971

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MISSOURI BOTANICAL GARDEN BULLETIN

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Illustration is from a woodcut of the marigold *(Calendula officinalis)* in William Turner's *A New Herball* published in London, 1551.

ANNUAL REPORT— 1970

From The Director

I KNOW OF NO institution which has more going for it today than does the Missouri Botanical Garden. It is an institution of beauty, pleasure, and learning and has, indeed, the best of both possible worlds. Shaw's Garden, as it is affectionately known in St. Louis, is a significant force in the life of the community and yet has international fame and respect as a scientific and horticultural institution.

The Garden is not wealthy, and in fact was in extremely serious fiscal difficulty for several decades. Instigating a number of procedures, such as charging admission to the Garden, working effectively with the Arts and Education Council of Greater St. Louis, improving food service, greatly enhancing the quality and quantity of sales at the Garden Gate Shop, and the procurement of grants has increased operating income to nearly keep pace with rapidly rising costs. A Capital Fund Campaign last year raised sufficient funds to allow the construction of the new John S. Lehmann herbarium-library-education building, to renovate many of our old facilities, and to improve endowment sufficiently to meet the operating expenses of the new building. Unfortunately endowment income has not kept pace with the increasing cost of living nor with the rate of increase of other income support. This has been a great disappointment to me since I am convinced that the generosity of concerned people could correct the endowment needs of the Garden.

Today men have on their consciences the realization that they are fouling their own nest, molesting their environment, and are eroding the quality of life for all future generations. The Missouri Botanical Garden has the experience and expertise, as well as the scientific collections and library, which will allow its staff to continue to help mankind chart its course in a world which will always depend upon living things.

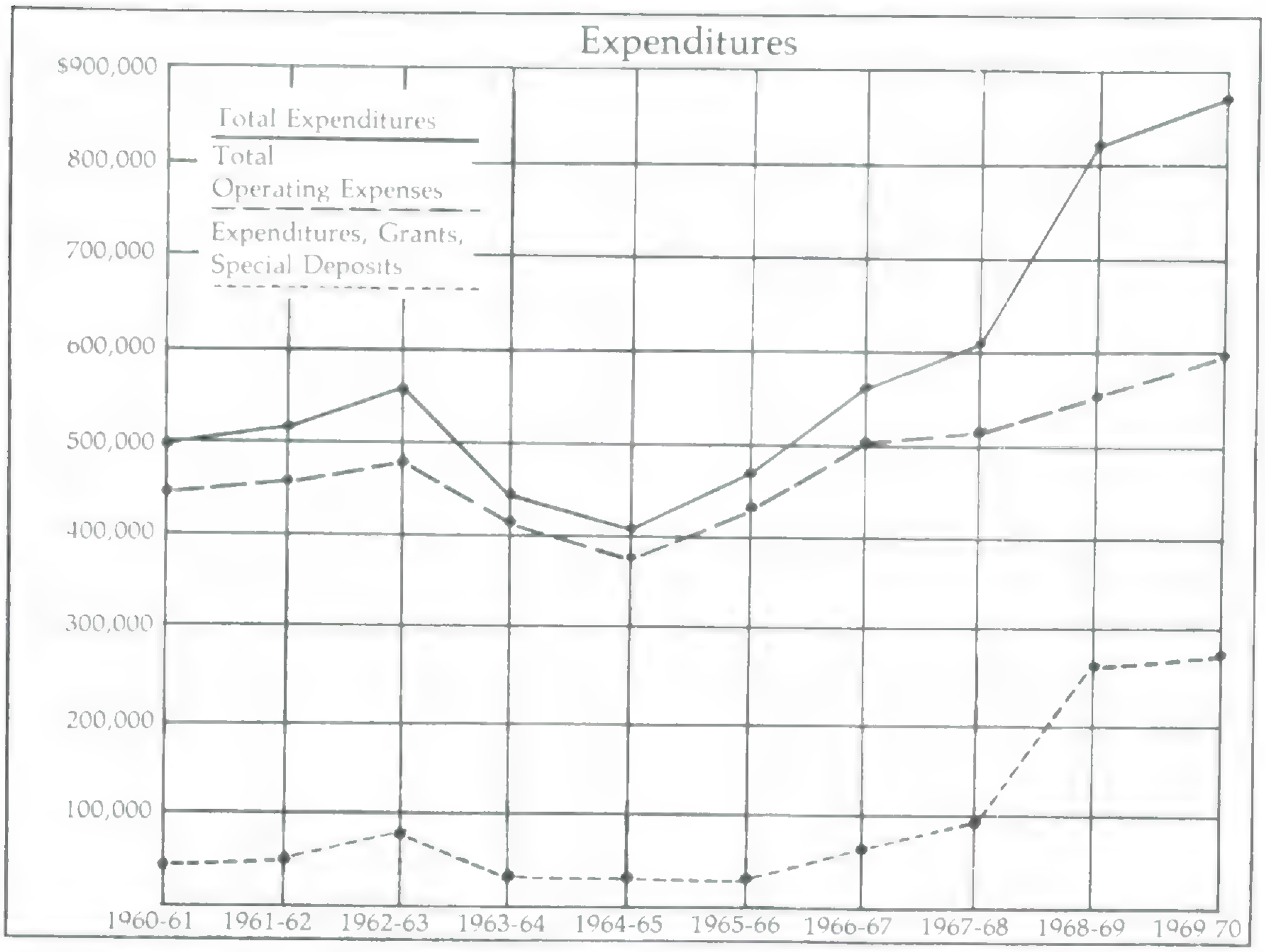
Claude Johnston

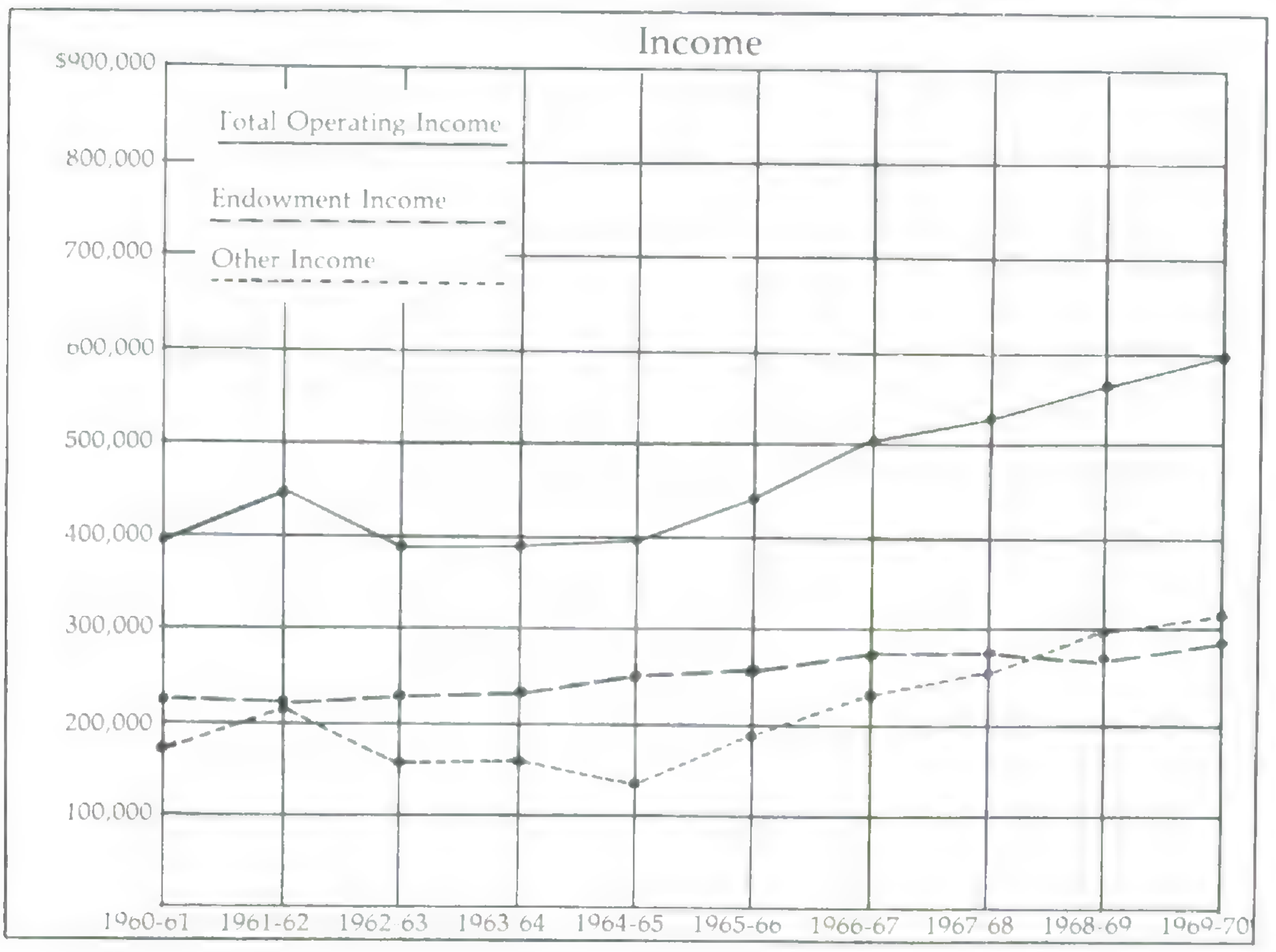
Dr. David M. Gates, Mrs. John S. Lehmann, and Board President C. Powell Whitehead broke ground for the John S. Lehmann Building on December 2, 1970. The new herbarium-library-education building is scheduled for completion in late spring of 1972.

A generous increase in the endowment of the Garden will allow its staff to continue making outstanding contributions towards man's understanding of plants. Compared with the plight of most institutions the endowment needs of the Garden are modest. Of course, any increase of endowment is helpful, but in order to have a stable, healthy, productive institution the Missouri Botanical Garden requires another $3 million. This is not very much money in terms of society as a whole. Yet if it is not achieved, the gap is a very serious one. The exciting thing is that a single individual or a few individuals could put this institution in good health for a long time to come. I am personally convinced that it can happen and will indeed come true. I will always, wherever I am, help to support the goals of this exciting and necessary institution. Good luck.

David M. Gates

Financial Summary, 1960-70





THE ILLUSTRATIONS on the opposite page give a graphic understanding of the Garden's financial affairs for the last ten fiscal years ending June 30, 1970.

The first half of the decade witnessed an annual operating deficit as operating expenditures were greater than operating income. Since fiscal 1965, the operating budget has essentially been in balance. Increased operating income has largely been due to sources other than endowment—this is especially true in the past five years.

Perhaps the most significant recent change is the seven-fold increase in expenditures from grants and special deposits. These funds are received in the form of grants and contracts for research and also as gifts earmarked for specific projects placed in special deposits. The procurement of grants, contracts, and special gifts are almost directly related to a more active role on the part of Garden staff in such activities.

Therefore, it is apparent that the long-term financial security of the Missouri Botanical Garden is related to an increase in endowment income. Other sources of income for operations and specific projects are subject to more transient factors. □

Claude Johnston

Businessmen tour the Growing Center in preparation for their work on the Arts and Education Council Fund Drive, which each year provides a substantial sum for the Garden's operating expenses.

Ecology

THE ECOLOGY GROUP, headed by Dr. David M. Gates, has been working on a model describing photosynthesis in terms of gas diffusion and enzyme kinetics. Predictions of photosynthesis and transpiration under a variety of environmental conditions are made possible by this model. Photosynthesis is the basic process by which green plants convert solar energy, carbon dioxide, and water to food. This process provides all food energy and oxygen for all living things. For this reason the model is an extremely valuable research project.

Field work during the summer of 1970 was done at the University of Michigan Biological Station and included continuation of work on the photosynthesis model. Dr. Christa Schwintzer and Dr. S. Moreshet also examined the microenvironment including relative humidity, temperatures, and radiation of a peat bog. Of particular interest was the rate of water use by the bog vegetation and possible relationships between the environmental conditions and the leaf morphology of the dominant shrubs. Dr. James Spotila and Dr. Oscar Soule's work included microenvironments of salamander habitats.

A series of fall ecological trips to study various habitats in Missouri were made. The first trip was to the Arboretum with a discussion by Dr. Porter on local flora. A two day excursion on the Current River was also taken by the Ecology Group. Dr. Cutler accompanied the group and described various aspects of river ecology. Tucker Prairie near Columbia, Missouri was visited to consider prairie soil structure and common prairie plant species. Dr. Claire Kucera from the University of Missouri guided the group. A natural limestone cave was explored during one of the field trips.

The Ecology Group has continued to work on various related projects involving past work as well as the development of new analytical approaches to improve our research.

Dr. George Bakken and Mr. Charles Puccia are studying the measurements of water use in an intact tree in the field. This will give us detailed information on how trees and their branches use water. An apparatus has been used by Dr. Bakken that pumps water

through a branch to test various techniques before actual field work is begun. Dr. Bakken came to the Garden in September from Rice University. Mr. Puccia is a graduate student in Electrical Engineering at Washington University.

Dr. Lloyd Dunn received his doctorate from U.C.L.A. and has been at the Garden since the fall of 1970. His research there involved studying the water loss and CO_2 fixation of chaparral plants native to Chile and California in order to learn better how they have adapted to survive a long dry season each year. Here, Dr. Dunn has been developing a device to allow simultaneous measurements from a single attached leaf of water loss and CO_2 uptake under different light intensities, temperatures, and humidities.

Dr. Sam Ajiri, a native of Biafra (Eastern Nigeria), joined the Biophysical Ecology Group in November of 1970. He completed his Ph.D. at the University of Massachusetts and is concerned with boundary layer theories as applied to leaves. His work here pertains to transport co-efficients for simultaneous fluxes of heat and mass between the leaf and surrounding air. Knowledge gained here will be helpful in understanding plant mechanisms in food production. Dr. Ajiri has a degree in Food and Agricultural Engineering.

Two graduate students, Mr. David Aronow and Mr. James McCrum, began their studies at Washington University this fall.

Dr. Oscar Soule and Dr. Spotila have almost finished their research efforts and will be taking new positions in the fall of 1971. A combined work, completed in 1970, determined a climate space diagram for a medium sized alligator. This was used to re-examine some previous work done by other investigators and was also included in a discussion of the extinction of some of the dinosaurs. Presently, Dr. Spotila is working on effects of water loss on the energy budgets of amphibians. Dr. Soule took part in the Club Explorecion Deportes Aquatico Mexicana Rio Mezquital Expedition in the states of Durango and Nayarit in Mexico. This expedition was the first non-native group to cross this region from the mountains to the sea and to make collections of plants and animals for scientific purposes.

Dr. S. Moreshet, from Israel, has focused his efforts on a photosynthesis model regarding the water use efficiency of plants, and is examining theoretically what methods can be used to reduce water loss without affecting crop yeilds. This will be especially useful in

countries which are short of water. Dr. Moreshet is also interested in developing a field porometer for measuring stomatal behavior.

Continuing in the capacity of Assistant Project Director for Ecological Research is Dr. Paul Lommen. The mathematical and physical aspects of the photosynthesis model were worked out by Dr. Lommen and he has also helped in the research of other members of the ecology group. He and Dr. Schwintzer have spent considerable time writing and preparing the previously mentioned paper on the photosynthesis model. Dr. Schwintzer reviewed the literature on the various physiological aspects of photosynthesis to help determine the features incorporated into the photosynthesis model. She gave special attention to the extensive literature on photo-respiration and wrote an inhouse summary of it.

Dr. Jesse Bennett left the Garden in June for work at the University of Utah. His research here was primarily on the photosynthesis model and its relation to air pollution.

Dr. Hyrum Johnson accepted a position at the University of California, Riverside, after completion of two years of study on the problem of energy exchange between leaves and environment with particular emphasis on gas exchange and the influence of pubescence.

Dr. S. Elwynn Taylor left the Garden in mid-January, 1971. He finished his work for the Ph.D. degree which involved leaf size, leaf shape, and other adaptations of significance to plant survival.

Mrs. Sylvia Morhardt will complete her Ph.D. in June, after finishing her dissertation on the Belding Ground Squirrel which inhabits high mountain meadows in the Sierra Nevadas of California. Her research has combined the energy budget techniques with physiological and behavioral data in order to relate the success of the species to the habitat with which it is commonly associated. □

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Herbarium and Systematics

Claude Johnston

The two millionth number was stamped on a specimen of the red haw *(Crataegus mollis)*, state flower of Missouri, on July 1, 1970. At that time the Herbarium contained an estimated two and one-half million specimens. Dr. Walter Lewis and former Herbarium Supervisor Susan Verhoek-Williams are shown here with Mark Paddock and Dr. Marshall Crosby.

THERE HAS NEVER BEEN a greater need for the botanical curating and research that has been the backbone of the Garden's scientific work since its founding in 1858. The accelerating destruction of the natural environment has increased the need for the understanding of nature. Our systematics research and training program, which relies heavily upon the Herbarium's vast collections of preserved plants, increases the world's knowledge in this vital area.

The number of specimens incorporated into the Herbarium this year showed an increase over that of last year. Thirty-one thousand and eighty-seven specimens have been accessioned this past year, due primarily to exchanges of specimens with other institutions, gifts, purchases, and collections by staff members and others.

Specimens sent out on exchange from the Garden numbered 6,941 including cryptogams, and those specimens received on exchange numbered 9,475. The exchanges received came from many parts of the world including Finland, Germany, Mexico, Panama, Poland, Russia, and the United States.

The total number of specimens received as gifts was 1,205. This, however, does not include two large collections presented to the Herbarium. The first was a collection of African plants by Adele Grant presented through the University of California at Los Angeles. The total number of this collection is not known as yet because these specimens will not be curated until the new building is completed. The second was a large collection of duplicates, primarily European plants, from the British Museum received through the University of Iowa. Other specimens received as gifts came from institutions in Canada, Brazil, Venezuela, Hawaii, Rhodesia, Panama, Australia, Mexico, and the United States.

Two thousand nine hundred and four specimens were purchased by the Herbarium this year. These specimens were primarily African and were purchased through the F. B. and B. A. Krukoff Memorial Fund presented to the Garden last year specifically for the purchase of plants of Africa, the Middle East, and Australia. In December of 1970, the Fund was almost doubled which will no doubt dramatically increase the number of specimens from these areas to be purchased in coming years. The Garden is the official repository for African plants in North America and therefore this additional gift from Dr. and Mrs. Krukoff will be especially valuable.

The number of loans requested from other institutions by students and staff members numbered fifty-six and included 2,893 specimens. The number of loans sent to other institutions numbered 131 and included 12,587 specimens.

Dr. Tom Croat departed in March to become the curator of the Summit Herbarium in the Canal Zone and to continue his research for the flora of Barro Colorado Island. While in Panama, Dr. Croat has been doing extensive collecting for the Herbarium here and also for Summit Herbarium. He has collected on the Azuero Peninsula, in the Atlantic lowlands (Miguel de la Borda, Guasimo, Portobello, and Escobal), in Chiriqui Province, and in the cloud forests of Central Panama (Cerro Campana and Cerro Azul). While in the United States for the Symposium in October he made

trips to the Gray Herbarium, the New York Botanical Garden, and the Smithsonian Institution to examine herbarium specimens.

Dr. John Dwyer travelled to Guatemala and several Middle American countries, including Honduras, under the auspices of the Organization of American States and the Instituto Centroamericano de Investigacion Tecnologia Industria (ICATI). He collected approximately 1,500 numbers along with Mr. William Harmon, a pre-doctoral student at the University of Missouri/Columbia. In December, Dr. Dwyer visited the Museum d'Histoire Naturelle in Paris to check herbarium specimens.

Other members of the staff who travelled and made collections this past year were as follows: Dr. Walter H. Lewis collected in the Bahama Islands, Panama, and Texas. In September, he attended the A.E.T.F.A.T. (Association pour l'Etude Taxonomique de la Flore d'Afrique Tropicale) meetings in Munich, Germany. Dr. Lewis also spent a few days at the Conservatoire et Jardin Botaniques in Geneva and Kew and the British Museum in London.

A grant from the American Philosophical Society enabled Dr. Joan W. Nowicke to spend a month in London at the British Museum and at Kew. Dr. Nowicke photographed plant specimens collected in Panama by B. C. Seemann during the years 1847-1851. A list of these photographs will be published and made available to institutions interested in the flora of Central America.

Dr. Richard C. Keating spent time collecting in British Honduras. During the summer he was a faculty member of the Tropical Ecology Course, appointed through the Tropical Science Committee of the AUIE (Associated Universities for International Education) and was recently appointed Program Director for the 1971 course.

Dr. Duncan M. Porter collected in Tennessee, North Carolina, northwestern Arkansas (with Dr. Delzie Demaree and W. G. D'Arcy), and also at the Arboretum with Dr. Marshall R. Crosby. Susan Verhoek-Williams, Sheri Davis, and Terry Luikart collected on the grounds of the Garden. Marilyn Andreasen, Sheri Davis, Terry Luikart, and Norma Fowler collected at the Arboretum and in Franklin County, Missouri. Dave Spellman, as a botanist with an expedition from the University of Edinburgh, collected plants in the Belize District of British Honduras. William G. D'Arcy collected in Panama, the Virgin Islands, and Puerto Rico, and northwestern Arkansas. John Semple collected in New England and West Texas.

Through the efforts of Dr. John Dwyer and his students some previously undetermined collections are being identified. Dr. Dwyer himself has continued his routine identification of recently collected Central American and Peruvian plants. Identification of Felix Woytkowski's Peruvian collection of over 3,000 plants was conducted on a team-work basis with Dr. Dwyer's students. A list of these identifications will be sent to any institution interested in Woytkowski's collections. Also, in connection with a course in plant identification taught on an inter-university basis through ISEB, many Mexican, Central American, and Peruvian flowering plants have been identified.

The Flora of Panama, of course, was still an active concern. The determination by various staff members and distribution to other institutions of specimens collected on previous trips to Panama has continued.

In September the Herbarium received a substantial grant, to be used over a three year period, from the Sunnen Foundation of

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Marilyn Andreasen, Herbarium Supervisor, opens the new compactor which has proven so useful in multiplying the storage capacity of the Garden's herbarium facilities.

St. Louis. This grant is being used for the hiring of much needed help in the Herbarium and for the purchase of supplies.

Collections in the Cryptogamic Herbarium have increased. Several thousand more mosses were put into new high quality packets and placed in the recently adopted vertical filing cases. In addition, several new exchanges were initiated which should bring valuable specimens to the Garden in years to come. An extensive collection of microscopic mounts of moss plants was obtained for the Cryptogamic Herbarium from Dr. H. S. Conard, author of many papers concerning mosses and also the popular guide "How to Know the Mosses."

An article concerning Mr. Leonardo Mourre and his work as a botanical illustrator will be contained in the next issue of G. H. M. Lawrence's *Botanical Illustrators* published by the Hunt Botanical Library. Leonardo is the illustrator for the *Annals* of the Missouri Botanical Garden.

A new facility, called the Compactor, was installed in the Herbarium Annex this year. The Compactor consists of a series of doorless cases which fit together tightly when not in use. To gain

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Leonardo Mourre works on a botanical illustration for the *Annals*.

access to the specimens the user turns a wheel at the end of the row and the bases slide apart creating an aisle. The algae, lichens, fern allies, and a portion of the ferns are housed in the Compactor. The Compactor was installed in the Herbarium Annex to test it for possible extensive use in the new building and it appears that it will be quite satisfactory.

In 1970 the *Annals* published a large issue devoted primarily to papers first presented at the 1969 systematics symposium. The theme of this symposium was "Tropical Island Biogeography," and the subject matter of the various papers ranged from fruit flies in Hawaii to mosses in the West Indies. Another number of the *Annals* published in 1970 was a continuation of the long series treating the plants of Panama. This issue of the "Flora of Panama" series included treatments of seven families of plants including the dogbane family (Apocynaceae) which has many representatives in Panama.

In 1971 it is hoped that a special issue of the *Annals* will be devoted to the memory of Dr. Edgar Anderson. The 1970 Symposium, "Hybridization, Evolution, and Systematics," was dedicated to Dr. Anderson and attracted over 200 botanists and zoologists. Dr. G. Ledyard Stebbins of the University of California, Davis, served as Moderator, and papers were presented by Dr. Lewis Anderson of Duke University, Dr. Leslie D. Gottlieb of the University of California, Davis, Dr. Norton Nickerson of Tufts University, Dr. Sarah B. Pipkin of Howard University, Dr. Robert K. Selander of the University of Texas, and Dr. Lester Short of the American Museum of Natural History. Dr. Charles B. Heiser, Jr., of Indiana University shared some early memories of Dr. Anderson at the evening talk that capped the Symposium.

During the year the Institute for Systematic and Evolutionary Botany added several new members. Joining from the University of Missouri/St. Louis is Dr. John E. Averett, a chemical taxonomist, who is working on a biosystematic study of *Goillardia* (Compositae) and a chemical study of the gypseous species of *Halopappus* (Compositae). Dr. Averett recently completed studies on the *Chamaesaracha* and the *Leucophysalis*, both members of the Solanaceae family. Two new members were elected from the Garden staff, Mrs. Erna Eisendrath, Botanical Historian and Mr. Kenneth O. Peck, Head Instructor of the Education Department. Members elected ex officio were: Dr. Lawrence D. Friedman of the University of

Missouri/St. Louis; Dr. John W. Hopkins, Washington University; Dr. Harold E. Manner, St. Louis University; and Dr. Richard B. Parker, Southern Illinois University/Edwardsville. The Institute, founded late in 1969, has continued to provide an excellent curriculum in systematics for undergraduates and graduate students. As a result of this consortium, many new inter-university courses were added for the Fall semester.

Research activities of the systematics staff and graduate students continue in several fields. In cytology, Dr. Walter H. Lewis and Mr. Royce L. Oliver have reported two new botanical phenomena: Chromosomal drift, which is the variation of the basic units of heredity around an environmental condition; and multiple genotypes in individuals, a phenomena in which chromosomal number may vary according to the part of the plant studied.

Mr. Terry Luikart continues his morphological and medical work with the Scanning Electron Microscope. Dr. Marshall R. Crosby continues his research on the classification and evolution of mosses. Dr. Duncan M. Porter is working on the Flora of Panama and Dr. Thomas B. Croat on the rain forest ecosystem of Panama.

These are only a few examples of the research being conducted by the systematics group in taxonomy, cytology, evolution, geography, ecology, medicine, floristics, and histology.

Two students received doctoral degrees this year. Bruce MacBryde finished his degree at Washington University in January and is now a Research Associate at the Instituto de Ciencias, Pontificia Universidad Catolica del Ecuador, Quito and has also been appointed to the Department of Biology at St. Louis University. The title of his dissertation was "A Revision of the *Galphimiinae*".

Daniel F. Austin also completed his doctoral degree at Washington University in August with a dissertation entitled "A Monograph of the American Erycibeae (Convolvulaceae): *Maripa*, *Dicranostyles*, and *Lysiostyles*." He is currently on the staff of Florida Atlantic University, Boca Raton, Florida. □

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Useful Plants

LAST YEAR, for the first time, we made comparisons of the total number of plants used by people at a single place and at a single time period with collections used by people in the past or at other places. The many specimens of useful plants from living peoples and from archeological sites which have been studied at the Garden provided most of the data. They show that changes in use and in the characters of a plant are often accompanied by related changes in patterns of use and in the evolution of other plants. This new approach provides a method to interpret inter-action of plant evolution and culture change, and will be especially useful in studies of food production and use in agricultural communities of underdeveloped areas.

Some of this research was supported by a grant from the National Science Foundation as well as contributions from other institutions for travel and assistance.

At the request of the U.S. Department of Agriculture's Northern Regional Research Laboratory we reviewed our corn collections for types which could contribute desirable characters to high protein

food for humans and other animals. Several ears among our Bolivian collections were selected to be bred with high-yielding strains in order to adapt short day Bolivian plants to corn belt growing conditions. Modern field corn is a selection from only a few of the many thousands of kinds the Indians grew for special purposes and environments. As we try to increase and improve our food crops, we will have to turn more often to collections like those assembled at the Garden in our search for different sorts of germ plasm.

Leonard Blake continued his work on archeological plant materials. Most of his time was spent on collections recently excavated from sites in the Mississippi River Valley. He visited many of these sites in order to demonstrate techniques for recovery, identification, and interpretation of plant materials. Largely as a result of his efforts, archeologists in this region have recovered more plant specimens in the past few years than in all previous years. With these collections we can study evolution in cultivated plants near St. Louis over a thousand year period. Agriculture here was well-developed in prehistoric times but was slow to change, probably as a result of influence from the great trade and ceremonial center of Cahokia.

Scholars frequently visit the Garden to consult the collections and to work with out staff. Dr. Martin Cardenas, Professor of Botany from Cochabamba, Bolivia, for example, spent June here, working on a revised edition of his book, *Plantas Economicas de Bolivia*. □

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Research Grants and Contracts in Effect in 1970

THE HEALTHY STATUS of the Missouri Botanical Garden in the world of science is reflected by the continuing strength of its research programs. The Garden receives a number of grants from various federal agencies as well as from national and local foundations.

This financial support makes it possible for the Garden to continue to play its important role in the world today, and provides funds for research associates, graduate students, research assistants, and helps our scientists obtain the equipment and tools so vital to their work. □

Title	Agency	Amount	Period
"Energy Exchange within Ecosystems"	Atomic Energy Commission	$ 24,900	1 year
"Biophysical Theoretical Ecology"	Ford Foundation	$420,000	5 years
"Maintenance, Repair and Renovation of MBG Library"	Green Foundation	$ 59,000	3 years
"Curatorial Operations of Herbarium"	Sunnen Foundation	$ 57,000	3 years
"Flora of Panama (4th Cont.)"	NSF	$ 73,500	2 years
"Identification of Archeological Plant Materials"	NSF	$ 7,086	2 years
"Maintenance and Curatorial Support of MBG Herbarium and Library"	NSF	$ 30,000	1 year
"Operating Support of MBG Systematics Facility in Panama"	NSF	$ 11,000	1 year
"Publication of Annals"	NSF	$ 29,300	3 years
Systematics Symposium (1970) "Hybridization, Evolution and Systematics"	NSF	$ 1,800	1 year

Library

THE MISSOURI BOTANICAL LIBRARY was able to begin work on several projects that had long been under consideration. This was made possible by two grants, one of $9,000 for one year from the National Science Foundation and another of $59,000 for three years from the Allen P. and Josephine B. Green Foundation. The National Science Foundation grant has been renewed for 1971, its third year.

Reclassification and recataloguing, which has been in the planning stages for several years, was begun after the employment of Miss Marion Koch as head cataloguer. Miss Leanne Miller, who joined the library staff in October, 1970, is assisting in the work of cataloguing and recataloguing.

After careful consideration of various book classification schemes, the Library of Congress Classification, with a few modifications, was adopted for our library. This classification offers many advantages including compatibility with the systems being used in the majority of research libraries.

Another important step in organizing the library's collections was the employment of Mrs. Brenda Gieseker as manuscripts cataloguer. The Missouri Botanical Garden has impressive holdings of manuscripts, but with the exception of the Engelmann correspondence this material has been scattered throughout the library in a completely disorganized state. Mrs. Gieseker will arrange, index, file, and calendar all manuscripts.

A useful publication listing scientific and technical periodicals in the Missouri Botanical Garden Library and the Washington University Libraries was issued during 1970 as Washington University's *Library Studies Number 6*.

Circulation statistics for our library do not reflect the true rate of use because researchers and students consult many books and periodicals in the library without finding it necessary to borrow them for extended periods for home or office use. Books borrowed totalled only 1250. In addition, 239 requests for interlibrary loans were filled. The library borrowed 25 publications from other institutions on interlibrary loan.

Although library users were primarily staff members and graduate students, there were many others who came from all parts of the United States as well as from foreign countries.

During the past year, cataloguers processed 668 titles consisting of 861 volumes. The library is currently receiving 1411 serial publications. Of these, 820 are received through exchange, 119 as gifts, and 472 as purchases.

Two foundation grants have already been mentioned. Other generous donors of funds were Mrs. John S. Lehmann and the National Council of State Garden Clubs. Mrs. Lehmann's gift was for the restoration of the magnificent eight volume set of Redoute's *Les Liliacées* by the R.R. Donnelley Company. The National Council of State Garden Clubs donations were for the repair and restoration of books.

A large collection of books, periodicals and pamphlets was received from the estate of Dr. Edgar Anderson. There were many other gifts, too numerous to mention here, from individuals, organizations and institutions.

With additional funds for the purchase of equipment and materials there has been vast improvement in both the quality and quantity of work done by the staff of book repairers and restorers.

Their total output was 433 books, many of which required exceptionally careful handling because of deterioration resulting from such things as air pollution and lack of humidity and heat control. The leather bindings of 500 volumes have been treated with preservative.

Most of our current periodicals are being bound by a commercial binder. A total of 419 volumes were bound in this manner during 1970.

Carla Lange and Eugenia Maddox attended the Conference on Botanical and Horticultural Libraries held at the Hunt Botanical Library, Pittsburgh, in April. A paper on Union Library Catalogues was read by Eugenia Maddox at this meeting.

Carla Lange continued to select from the library's collection of pre-Linnaean herbals the illustrations to be reproduced for the covers of the Missouri Botanical Garden *Bulletin*. For 1970 she selected woodcuts from Parkinson's *Theatrum Botanicum*. Her articles on this work appeared in the *Bulletin*. □

Education Department

J.M. Carrington

Each spring children come to the gardening courses given by the Education Department under the direction of Ken Peck, assisted by volunteers from the Men's Garden Clubs of Greater St. Louis.

ONE WORD THAT MIGHT aptly describe the efforts of the Education Department during 1970 is variety. Like so many activities in education, there is a constant need to review old materials, update, and even change them. One popular trend in adult courses is toward the workshop in which students spend more time working with plant materials than listening to lectures.

Four programs for children were offered by the Education Department. The oldest of these is the Pitzman Summer Nature Program, first given in the summer of 1958. The good fortune of this program has been the gracious financial support of the Pitzman Charitable Trust. For the first time, each child this year was charged

a small fee to help cover ever-increasing costs of materials. This had virtually no effect on the number of children who attended and seemed to reduce the attrition in attendance which is natural after the first two weeks of each session. The St. Louis Audubon Society played a bigger role than usual in the program by renting buses to take one entire group from each session to the Arboretum for a day. This was a new experience for the Education Department and for most of the children who came equipped for walking and collecting insects. The purpose of the trip was to let them visit natural areas under the guidance of trained naturalists. Lanier Criger once again organized her Audubon staff for teaching the course in bird study.

The second oldest children's program is the Saturday Morning Program, which also began in 1958. A fifteen-cent per person charge, effective last September, has made children more selective in choosing the programs they wish to attend. The most popular programs are those in which children plant bulbs or cuttings and make terrariums or Christmas wreaths. It was estimated that 425 people made wreaths for Christmas 1970. There is an increasing and welcome trend for parents to sit in on the classes with their children.

Approximately 7,000 students and teachers participated in the very popular Plant Science Lectures and Workshops. This is a program in which a teacher may arrange to bring a class to the Garden for a botany lesson. The Workshops are expanded sessions in which students learn to identify plant materials.

The volunteer Garden Guides are now leading most of the Garden tours. The Education Department still gives tours to high school and college biology and ecology classes. Department members led 2,200 people on their 1970 tours.

The most popular new adult courses and workshops were the two terrarium courses using woodland and tropical plants, "Ecology and the Environment," and the "Christmas Decoration Workshop." The course in "Herbaria and Herbarium Techniques" was well-received. Other new courses included "Patio Gardening" and "Plant Communities". Our two basic courses in raising plants from seeds and cuttings consistently draw full registrations year after year, as does "Home Orchid Culture."

One adult activity that the Education Department enjoyed setting up for was the European Floral Design Festival, co-sponsored by the Garden and Florist Transworld Delivery (FTD). Six Belgian

florists demonstrated European methods of floral design, and the arrangements they made were sold to the people who attended. Mrs. Landon Jones and other volunteers conducted the sale and the proceeds went to the Garden.

The Education Department is now setting up instructional displays monthly in the Growing Center. The largest display was the one featuring early spring wildflowers. This was followed by a display of common weeds which was very popular. The display of plants damaged by air pollutants such as ozone and sulfur dioxide was of interest but we found that it was very difficult to damage plants with pollutants short of killing all the foliage! The fall display featured squashes and pumpkins and their new world origins. A display of cones and cut branches of conifers made an interesting botanical treatment of Christmas materials. These displays depend greatly on the artistic ability of Sandra Thornton.

Miss Thornton was given an Audubon Nature Camp scholarship by the local Audubon Society and attended the Wisconsin Camp, which she found very rewarding.

Mrs. Shirley Barnett helped us coordinate all of our activities.

Horticulture

MANY CHANGES OCCURRED in Horticulture in 1970. The first big event was the opening of the Growing Center in March. This new facility was created through funds raised by the Friends of the Garden during the first Plant Sale in October 1969. The Growing Center is located just off the Floral Display House and is manned by volunteer guides who conduct tours and do the general maintenance and upkeep of plants in the area. Exhibits on growing and propagating plants, as well as special lectures on gardening, have added a great deal of interest for groups visiting the Garden. Later in the year an office for the Public Services Coordinator was added to the Growing Center.

In October, renovation of the American Desert House was finished and the building was again opened to the public. This display uses a new technique that gives the visitor an ecological impression of the American desert. We have received much good reaction from the public on this new display.

In the Floral Display House brick planters were added to the upper level and redwood panels installed in the main area to conceal heating pipes and add a more suitable background for floral displays.

Hardy chrysanthemums were planted in an area south of the new Desert House and give a pleasing colorful effect in autumn when viewed from several areas.

An organic vegetable garden was set up under the direction and care of Bill Davit. It created considerable interest and will be a permanent feature each year.

The Boxwood Society under the leadership of Mrs. D. Goodrich Gamble was successful in collecting approximately forty

A beautiful Japanese garden, designed by Roy Fisher and Jim Rhodes, was the focal point of the 1970 Chrysanthemum Show and Preview Party.

different varieties of boxwood. A test area was set up in the Garden, and over 800 plants were planted late in the summer. Plans call for establishing a boxwood garden in memory of Dr. Edgar Anderson, and we hope to start on this in the spring of 1971.

Early in the year we were successful in securing the services of Leroy Fisher as Greenhouse Superintendent and James Rhodes as Assistant. They have made a number of improvements in growing, such as adding automatic watering to part of the growing range. Through improved methods of growing, chrysanthemums for the fall show were produced in about half the time required in the past. Better use of the growing space has been made possible by rearrangement of growing benches and the installation of more automatic watering.

Alfred Saxdal was made Grounds Superintendent, and under his watchful eye, vast improvements were made. An automatic water system was added to the area between the main gate and the Climatron. Lawn renovation was carried out in this area and in front of the Desert Houses. Other parts of the lawns and shrub areas received increased maintenance, giving a neater appearance to the overall grounds area. A number of new pieces of power equipment were purchased as part of the Capital Fund Drive renovation project, thus enabling the grounds maintenance crew to make a large increase in productivity and efficiency.

The horticulture operations of the Garden receives a great deal of aid and support from the St. Louis Herb Society. Aside from maintaining the Herb Garden, they volunteer help in the greenhouses and their annual herb sale produces much needed funds for horticultural supplies and equipment.

We also receive volunteer and financial support from a number of other groups and individuals. Without this support it would be difficult to continue to make needed improvements.

Through the cooperation of the Men's Garden Club of St. Louis, the "Answer Man" service flourished in 1970, answering 7,209 calls pertaining to gardening and horticulture. Each morning during the warmer seasons an expert gardener is on hand to receive calls from the general public. When the caller wishes to have advice from some specialist on the Garden staff, the "Answer Man" takes his number, and after consultation, calls the individual back with the requested information.

The past school year our Garden staff has been working with twenty Soldan High School students on a horticulture work-study program sponsored by the U.S. Department of Health, Education and Welfare through the St. Louis School Board.

The program entitled Project Stay, is an effort to encourage students to stay in school to complete their high school education while learning a vocation they can pursue after graduation. Two groups of students spend half days in the Garden and then attend school during the other half day. The students spend much of the time on the job receiving practical experience while classes are periodically held to help the students acquire the theory to aid in basic skills and knowledge of maintenance in the various aspects of horticulture.

In one regard 1970 witnessed the end of an era at the Missouri Botanical Garden. Mr. Paul Kohl, who was associated with the Garden for over 50 years, retired at the end of the year. For over 40 years, Paul Kohl created the beautiful floral displays enjoyed by millions of people in the Floral Display House. A man of immense integrity, intelligence and devotion to his task, Paul Kohl has become a legend in his own time. □

The Arboretum

THE ARBORETUM IS BECOMING a greater source of interest and activity appropriate to a facility of its unique beauty and natural features. During the summer the National Park Service and the Arboretum coordinated a program on environmental awareness (Project NEED). Over 1,500 city children spent time at the Arboretum, enjoying and learning first hand about the natural environment. The St. Louis Audubon Society and other natural history groups continue to use the area for nature walks and classes. A Washington University program at the Arboretum farm continued with its fourth group of students. The experience of studying and living for a semester in a rural environment, a unique situation for students predominantly from the city, has shown itself to be an effective educational

tool. Plans for a more rigorous program are being considered by the University and Garden.

This fall a number of important changes occurred. Mr. Frank Steinberg retired as superintendent, having been associated with the Arboretum since 1927. The excellent condition of the facility today is a tribute to his careful and conscientious management. The fall also marked acquisition of two important new pieces of property. Mrs. Stratford Morton donated her beautiful Persimmon Hill, 253 acres located along the southwest corner of the Arboretum. The Garden then purchased another farm, belonging to the Bair family, lying along the western edge of the present farm and easily visible from the bluffs of the Morton's and the Arboretum. This protective action came at a time when developers are acquiring numerous holdings in the area to accomodate the westward sprawl of St. Louis. The Arboretum now can protect nearly three miles of the scenic Meramec River for enjoyment and study.

Perhaps most significant to the future of the Arboretum was funding of a basic program to develop it as a center for environmental education. Scheduled to begin in the spring of 1971, it will encourage public use of the Arboretum, and promote an increased understanding and appreciation for the beauty and importance of our natural environment. For too long man has been guilty of a gross misuse of the land, air, and water which support his life. Increasing population with its consumptive technology demands an enlightened responsibility for this environment of which man is an inextricable part. The Arboretum provides an unsurpassed facility and opportunity for providing the public with insights into the ecological as well as aesthetic necessity of adopting a new environmental ethic based upon man working with nature.

Two major roles of the Garden are education and research. It is appropriate and important that we, as a vital community institution, take an active role in environmental education and research. The Arboretum has the potential to have one of the most outstanding environmental education programs and natural history research areas in the nation. The Garden has the talent to make it so. We are now taking the first small step toward that goal. □

Maintenance and Engineering

A NUMBER OF PROJECTS were completed in 1970 as part of the renovation begun at the Garden in 1965. Acceleration of this program was possible as funds from the successful Capital Fund Drive became available and were earmarked for the renovation projects.

Under the expert guidance of Mr. Jim Hampton, Chief Engineer and Superintendant of Operations, long-standing maintenance needs have been met, such as the cracked stone steps and rusty eroded rails on the south entrance to the Museum which were finally repaired with new stone and recast ironwork. For many decades this was an unfortunate eyesore on this, one of the Missouri Botanical Garden's original buildings built by Henry Shaw.

The service entrance on Alfred Avenue was completely refurbished. The buildings in the maintenance area were equipped with sliding doors, and a vast maintenance and storage room was created out of the old coal bin near the boilers. Over 3,000 square feet of bright, clean, useful space was prepared using a little ingenuity and a lot of effort on the part of our resident maintenance staff.

Two greenhouses were completely renovated, and the Desert House mentioned in more detail under "Horticulture" was

Claude Johnston

These before and after pictures clearly show the vast improvements made on the south entrance of the Museum.

completely remodeled. Our carpenters, electricians and other maintenance personnel put many hours into the creation of a Growing Center and office for the Coordinator of Community Services.

This renovation program will continue for the next few years using funds earmarked for this purpose in the Capital Fund Drive. As renovation progresses, maintenance costs diminish and efficiency of operation increases.

The maintenance and engineering staff are heavily involved in tasks related to the new John S. Lehmann Building, now under construction. Some of the work pertaining to this new building is being done by our own staff. Mr. Hampton has had to dovetail tasks relating to the construction of this new building into his normal workload.

We are extremely fortunate to have such a conscientious and productive maintenance department at the Missouri Botanical Garden. The efforts of these staff members are becoming more apparent daily. □

Friends of the Garden

IN 1970, THE FRIENDS of the Garden continued their financial support of the Missouri Botanical Garden through annual membership contributions, profits from the Garden Gate Shop, the Annual Plant Sale, and the Spring Fiesta Trip. The Friends also played a large part in the expansion of the Garden's community services.

Friends activities doubled under the direction of the enthusiastic President, Mrs. Walter G. Stern, who was assisted by the Women's Executive Board, and many other volunteers who helped make 1970 the most exciting year in the Friends' thirty-one year history.

The Garden made 500 new Friends as the result of an extensive membership drive under the direction of Mrs. C. Carroll Stribling, Sr., Chairman. Her committee spent innumerable hours collating lists, and sending invitations to "Become a Friend of the Garden."

The second super plant sale was held October 3, with proceeds going for the construction of the community services office adjacent to the Growing Center. In addition to plants grown at the Garden, material not usually available commercially was brought in for this sale. Volunteers stocked the shelves and served as salespeople under the direction of Co-Chairmen Mrs. Tom K. Smith, Jr. and Mrs. Donald J. Sher.

In early April, thirty-five Friends joined Dr. and Mrs. Gates for the Spring Fiesta Tour to New Orleans. They toured private gardens in the Vieux Carre and the Garden district and participated in the city's Spring Fiesta. Each traveler contributed fifty dollars to the Garden.

May 6 was Friends Day at the Garden and included guided tours, a talk on ecology by Andy Johnson, rides on the Flower Wagon, a gift plant for each Friend, and gourmet box lunches served in the Floral Display house.

Three workshops were held for the membership. In June, Bob Dingwall and Al Saxdal of the Garden staff, assisted by members of the St. Louis Rose Society, lectured and then took guests on tours through the rose gardens to give practical hints on rose care. In August, Nelson Russell gave instructions on fall lawn care. December 1, Mary Gamble presented a talk on the history of herbs and Virginia Schreiber discussed the use of herbs in the kitchen, in the beauty ritual, and in creative housekeeping. That afternoon, Jim Rhodes demonstrated the use of natural materials in making Christmas decorations.

Preview parties, held on the Friday evening before the floral displays are opened to the public, continue to be the Friends most popular event. The Orchid Show Preview in February included a preview of the new Growing Center. The Spring Flower Show Preview was held in March, and the Chrysanthemum Show Preview was in October. The Christmas Flower Show Preview is especially for children and grandchildren of members. Our very special Garden Santa arrived December 12 in a gaily decorated motorized cart and gave each guest a tiny, live pine and a candy Christmas tree.

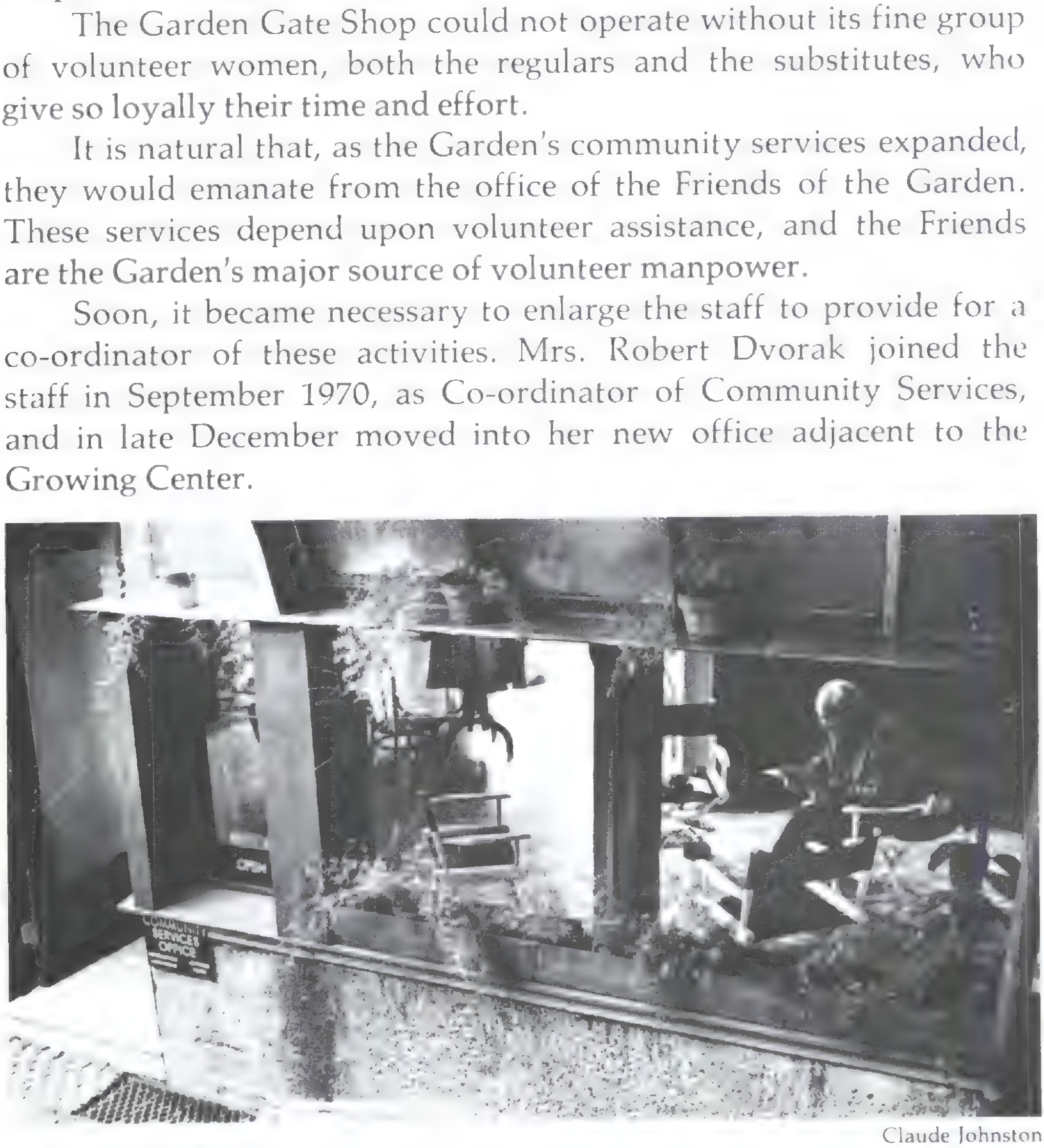
The Garden Gate Shop enjoyed another very busy and profitable year. Gross sales were double that of the first year, of the present Shop and twenty five per cent above 1969.

The Shop was redecorated in 1970 and new book shelves were added. The small storeroom, refurbished and given over entirely to books, is now a good place for customers to browse and buy. With the expanded book department, the shop is becoming known as "the" place to look for all books on gardening and nature. It has that reputation for those "special" gifts. Co-Chairmen Mrs. E. Lawrence Keyes, Jr., Mrs. Holland F. Chalfant, Jr., Mrs. Alexander Cornwell, Jr., devoted much of their time to the managing of the shop, under the direction of manager Mrs. Edwin R. Stuessie.

The Garden Gate Shop could not operate without its fine group of volunteer women, both the regulars and the substitutes, who give so loyally their time and effort.

It is natural that, as the Garden's community services expanded, they would emanate from the office of the Friends of the Garden. These services depend upon volunteer assistance, and the Friends are the Garden's major source of volunteer manpower.

Soon, it became necessary to enlarge the staff to provide for a co-ordinator of these activities. Mrs. Robert Dvorak joined the staff in September 1970, as Co-ordinator of Community Services, and in late December moved into her new office adjacent to the Growing Center.



Claude Johnston

The Community Services Office, just off the Growing Center, was built in 1970 and schedules the Garden's lectures, tours, and various facilities.

The Community Services Office provides tours for children and adults by the Garden Guides, lectures on horticulture by the Growing Center Guides, luncheons, speakers' bureau, and the scheduling of Garden facilities.

The third year of the volunteer guide program began in September with a program which included two meetings a month September through November. A Garden staff member lectured on topics ranging from the plants of the Desert House to the projected Library-Herbarium building. Several new tours were added to the guides' repertoire: Historical Tour, Bloomin' Tour and Herbarium-Library Tour. Over 85% of the guides attended all sessions, which is an indication of the interest and devotion of these volunteers. From September to December of 1970, there were 700 more people who came for guided tours or an increase of 23% over the same period in 1969. □

Tower Grove House

TOWER GROVE HOUSE is unique among the Victorian houses of our nation, not only because of it's famous tower, rising above the two story stone, brick, and stucco residence, and the authenticity of its furnishings, but also because it is set in the beautiful surroundings of the Missouri Botanical Garden. Visitors interested in the Garden's historical aspects are rewarded with views of Tower Grove (originally Shaw's country home), the Museum, Henry Shaw's city home (the administration building), and Linnaean House, all built by Mr. Shaw in the nineteenth century.

The Historical Committee is pleased to report that approximately 40,000 visitors came to Tower Grove House in 1970, including many groups of school children. Under the efficient direction of Mrs. Virginia M. Brewer, our manager, eighty hostesses were on duty seven days a week. Some were on a regular weekly schedule, others as needed when large groups were scheduled.

Mrs. William G. Bowman arranged two "thank you" teas for our hostesses, one in the spring, another in the fall.

Claude Johnston

Mrs. W. Warren Kirkbride, Chairman of the Historical Committee, converses with Mrs. David Gates (left) and a volunteer at the November tea given for Tower Grove House volunteers.

Henry Shaw's birthday was celebrated on July 26th with a group of 50 talented young people from "Sing Out St. Louis West" who performed on the lawn on the west side of the house.

The Executive Board of the Friends of the Garden held their meeting in September in Tower Grove House. The ground breaking ceremonies for the new John S. Lehmann building, held in December, were centered around Tower Grove House where refreshments were served after the ceremony.

Beautiful arrangements of fresh flowers were in the house at all times, thanks to a special group of volunteers. The dried flower arrangements throughout the house are the creations of Mrs. Mary Baer and Mrs. Frederick Robinson.

The decorations at Christmas were in the Victorian style; the large Christmas tree was hung with strings of cranberries and popcorn and authentic old decorations. The house was decked with

evergreens and holly and boxwood. With very little imagination one could almost smell the Christmas dinner cooking, because the kitchen was a perfect recreation of Christmas hospitality.

A new book entitled *Treasure Rooms of America's Mansions, Manors and Houses*, by Rita Reif, devotes four pages of description , with colored pictures, to our Tower Grove House.

Member of the Historical Committee are Dr. David Gates, Mrs. W. Warren Kirkbride, Chairman, Mr. George Brooks, Mrs. William G. Bowman, Mrs. John S. Lehmann, Mrs. Neal Wood, Mrs. Jerome F. Kircher and Mrs. John S. Wagner. □

Public Relations

EVERY TIME A NEWSRELEASE is sent out by the Public Relations department, it goes to eighty news media and includes all the dailies and weekly newspapers in the Greater St. Louis area, as well as the radio and television stations, local magazines, and important people involved in public relations work. Over 3,700 lines have been published from the newsreleases alone. In addition, many photographs and feature articles on the Garden have appeared in newspapers, magazines, and books. Radio and television coverage was good during the year and always brings out visitors.

Many special displays were staged in hotel, bank, and school lobbies during the year. The exhibits included ornamental as well as flowering plants, photographs of Garden facilities, rare cacti and succulents, orchids, and a model of the new Library-Herbarium-Education building.

The year 1970 was a busy year for lectures by the Garden staff members. More than 200 lectures and slide talks were given to garden clubs, civic, and other community organizations.

For a number of years the Garden has been distributing color brochures to travel agencies, auto clubs, conventions, and hotels. During 1970 over 22,500 of these brochures were sent out to local as well as outstate organizations. About 15,000 went to the Convention and Tourist Board of Greater St. Louis and the Visitors Center.

Three special Sundays were set aside during the warmer seasons as an experiment to increase attendance at the Garden. The first, an International Day and Art Festival on June 21 drew 2,764 visitors, even though the day was rather cool and overcast. Seventy-two artists from the South County Artists Association began setting up their exhibits at 8:30 a.m. and dancers entertained all afternoon.

July 19th was proclaimed Henry Shaw Sunday by Mayor Cervantes to celebrate the 170th birthday of the Garden founder, but because of heavy rain the celebration was postponed to the following Sunday. "Sing-Out St. Louis West," 50 singers and musicians, gave a stirring two-hour program for 1,716 people.

On October 4th the Carla Jo Dance Studio and the International Folklore Association held a native costume and dance show on the Knolls with Miss Patti Teper of KFUO as commentator. The day was ideal and 2,980 attended.

During the year many important visitors come to the Garden, some incognito and others who make advance appointments. To make their visits pleasant and profitable, we often give time to these people and guide them around the facilities. These included directors of other gardens, local and national celebrities and other professional and business representatives. □

Publications Department

THE BULLETIN OF THE Missouri Botanical Garden was published on its regular bi-monthly schedule in 1970, and the six issues averaged thirty-five pages.

Circulation of the *Bulletin* has continued to creep up this past year, so that we are going into the new year expecting to print a minimum of 4,000 copies per issue in 1971. This is due, in great part, to increased interest gained through the capital fund drive as well as the very successful membership drive of the Friends of the Garden. As more and more individuals learn of the Garden's important place today in the fields of botany, ecology, and horticulture, our subscription numbers are rising also.

In the light of our unavoidable increased costs, we have raised the price of our *Bulletin* subscriptions from $3.50 per year to $5.00 a year for domestic subscriptions; $6.00 a year for foreign subscriptions; and $1.00 for each individual copy.

We continue to aim for a balance of articles, subjects, and content in our *Bulletin* that will give a comprehensive feeling for the Missouri Botanical Garden in our world today. The Garden is important to, not only our St. Louis community, but also the worlds of science and horticulture. Articles on subjects relating to our world-famous library and herbarium, as well as those on horticulture and our research projects in ecology, economic botany, and systematics help to keep the Garden's public informed of current trends in those many fields for which the institution is famous.

The Publications Department published one special in the year 1970. This was "The Climatron" which was first printed in the July-August *Bulletin*, and then made up as a reprint to sell as an adjunct to individual and group tours. Profits from this booklet as well as others such as the herb booklet and the Henry Shaw biography, published in 1969, are being put into a special account that will be used to print other special booklets.

The Publications Department also produced the monthly newsletter, *The Garden Today*, throughout the year of 1970. Ten issues were printed, one for each month except July and August. This newsletter, begun as an offshoot of the Capital Fund Drive, proved its worth in several ways. It relieved the *Bulletin* of ephemeral news such as the monthly calendar, local Garden events, promotional material for the Garden Gate Shop and Tower Grove House, and news of the Garden's auxiliary Friends of the Garden. This kind of news is ever so important on a local level as well as being a record of what staff members are doing and accomplishing in their own fields.

The Publications Department looks forward to publishing more special booklets that will tell the Garden's story to not only our St. Louis audience but also the increasing number of people throughout the world who are interested in growing plants and learning more about botany and ecology as well as the resources and people who work behind the scenes at our Missouri Botanical Garden. □

AN AMATEUR BOTANIST'S GREAT DISCOVERY

Dana K. Bailey and Pinus longaeva

David M. Gates

A KEEN EYE, a sharp mind, and the systematist's ability to arrange the elements of a plant into orderly comparative patterns of detail led Dr. Dana Bailey to recognize a long-known population of pines as a new species, the "Great Basin" bristlecone, *Pinus longaeva*, whose oldest living contemporary members reach ages of about 5,000 years. The oldest sequoias of Big Trees of California probably do not quite reach 4,000 years. You and I would have thought that all the pines of the world, about 100, were known since they are so conspicuous. So also would a good many botanical experts who have studied pines for much of their lives, insofar as pines occurring in the United States are concerned.

How could we then have expected a geophysicist, who is expert in electronics, radar, telecommunications, and the ionosphere, to come down to earth and point out to the botanists that there was a hitherto unrecognized species of pine in their midst? But Dr. Bailey is no ordinary geophysicist, nor for that matter is he an ordinary

scientist but one whose interest was so intense in botany, astronomy, and geophysics that he had to make a difficult career decision while a student at the University of Arizona in 1933. Professor A. E. Douglass, the great Arizona astronomer, who evolved the powerful techniques of tree-ring dating, and Professor E. F. Carpenter, convinced Bailey that he would do better studying astronomy there instead of botany.

Often extending to timberline along the wind-swept upper slopes of mountain ranges of the Colorado Plateau and the Great Basin of southern Utah, Nevada, and the White Mountains of eastern California exist today the oldest known living things on earth, the Great Basin bristlecone pines. Season after season for as long as 5,000 years a certain few of these pines have grown and added minute yearly rings of wood (sometimes as many as 200 to the inch!) to their worn and weather-sculptured trunks. Relatives of these bristlecone pines are a group growing farther west in the Sierra Nevada Mountains of central California and in the Klamath Mountains of northern California known as foxtail pines, *Pinus balfouriana*. To the east in the Colorado Rocky Mountains and in the Sangre de Cristo Mountains of Colorado and New Mexico are other stands of pines, also relatives of the Great Basin bristlecones and known as *Pinus aristata*, the "Rocky Mountain" bristlecone pines.

Although these related trees found in central and northern California, and in Arizona (one very small stand), New Mexico, and Colorado do not exceed about 2,000 years in age, they are, nevertheless, of great interest to scientists from the Tree Ring Laboratory of the University of Arizona. In 1907 Dr. Douglass began to develop ideas which eventually made possible the exact determination of the age of relic timbers of ancient Indian dwellings in the Southwest by matching characteristic patterns of growth rings from tree to tree back in time. It was Dr. Douglass' interest as an astronomer in variations of solar radiation and climate which led him to study tree rings for evidence of such variations. Dr. Bailey pursued, as a hobby, his interest in tree-ring dating, dendrochronology, which he had acquired as a student at Arizona. He spent weekends in the Rocky Mountains of Colorado seeking specimens of Rocky Mountain bristlecone pines in the hope of finding stands of trees with specimens comparable in age to the 4,000 to 5,000 year old veterans reported from Nevada and eastern California.

Dr. Dana K. Bailey, geophysicist, recently described a previously unrecognized species of pine in the American Great Basin region.

After some five years of searching without finding any unusually long-lived specimens in Colorado he decided to move his explorations to the westward into Nevada and to the White Mountains of California. In late August 1968 some of the very old trees were located and examined in the Snake Range (Wheeler Peak Scenic Area) of eastern Nevada and on Pearl Peak in the Ruby Range of Elko County, Nevada.

At once Dr. Bailey realized that he was seeing trees which appeared distinctly different from those he had been seeing in Colorado. No longer did the needles have the conspicuous resin exudations, called "dandruff", of the Colorado trees. By then Dr. Bailey had begun to study the taxonomy of the bristlecone pine in detail. Dr. George Engelmann (1809-1884), that great St. Louis botanist and physician, confidant of Henry Shaw who convinced Shaw to establish the Missouri Botanical Garden, was the first to recognize

the bristlecone pine as a new species, *Pinus aristata*. In making a precise description of this pine, collected by Dr. C. C. Parry in 1861 on Pikes Peak and on the mountains of Upper Clear Creek, Colorado, Englemann noted that the needles contained mainly single resin ducts along their length. Dr. Bailey in 1968, more than one hundred years later, besides confirming Engelmann's findings about the Colorado trees, decided that he had better look at the resin ducts in his "dandruff-free" trees of Nevada, as well as examine closely needles of the foxtail pine, *Pinus balfouriana*, growing still farther west in California. He confirmed that the foxtail pines have two resin ducts per needle. Furthermore, and most significantly, he found that the bristlecone pines of Nevada also have needles with two resin ducts.

By then Dr. Bailey's curiosity was really whetted and he pursued his detective work with even greater intensity. More field trips were made, numerous specimens were collected from all over the west, and 17 herbaria, from coast to coast, were visited. He wanted to know exactly what it was that earlier explorers had found and how the identification and naming of their pine specimens had proceeded. George Engelmann, when he described *Pinus aristata*, was unaware that Greville and Balfour in Scotland had described as *Pinus balfouriana* specimens of the foxtail pine collected by Jeffrey in 1852 in the Klamath Mountains of northern California. Moreover when Engelmann used Parry's collection from Colorado to describe *Pinus aristata* he was unaware of several older but unstudied foliage specimens collected by the western explorer John Fremont in Colorado in 1844 which were deposited in the U.S. National Herbarium in Washington, D.C. and in the Gray Herbarium at Harvard. Engelmann did, however, know of the foliage specimens collected during Gunnison's Pacific Railroad survey in the summer of 1853 from Cochetopa Pass in Colorado and now deposited in the Gray Herbarium and in the herbarium of the New York Botanical Garden. These latter specimens had remained unstudied for want of cones.

By about 1871 Engelmann had learned of the description of *Pinus balfouriana*, and in 1880 when he published a revision of the genus *Pinus* he combined the foxtail-bristlecone pine complex into a single species which, on the basis of priority, was called *Pinus balfouriana*. He thereby downgraded *Pinus aristata* to a subspecies

Author photo

This specimen of the Great Basin bristlecone *(Pinus longaeva)* shows the characteristic erect, and almost parallel branching.

of variety probably on the basis of later specimens that came to him from Nevada and California, and probably without re-examining the original material from Colorado collected by Parry. This downgrading was not accepted by later botanists who have maintained *Pinus aristata* as a true species. Part of the trouble was probably related to the fact that the original description of *Pinus balfouriana* was somewhat inaccurate and suggested that the foxtail pines differed more than is actually the case from the bristlecones. Engelmann also had in his possession at the Missouri Botanical Garden a specimen collected by William Gabb in 1867 from the eastern slopes of the White Mountains in California which he had annotated as *Pinus aristata* var. *decurva*. Thus, interestingly, Engelmann had noted particular characteristics of this specimen and had contemplated separating it as a subspecies from the Colorado specimens which he had described a few years earlier.

Bailey, while delving into all these interesting historical facts, had continued to pursue his detailed comparative studies of the foxtail bristlecone pine complex from California, Nevada, Utah, Arizona, New Mexico and Colorado. He not only studied critically the needles for position, size, and number of resin ducts, but also the cones and seeds. He then studied the color of the wood and bark, the resin odors of the trees, and their growth forms and appearance as to "dandruff" or no "dandruff." Following this he pursued all the chemical analyses of gum turpentines of these trees which had been done by various investigators. Bailey also investigated what was known of the paleobotany and paleogeography of the western mountainous region of the U.S. in order to learn the possible migration routes by which these pines reached their present positions. He understood how the trees growing in the mountains of eastern California, Nevada, and Utah became isolated and distinct during approximately the last 5 million years from those now growing in the Sierra Nevada farther west and the Klamath Mountains of northern California, and how, still longer ago, the Rocky Mountain bristlecones of Colorado, New Mexico, and Arizona became distinct.

Then after consulting with numerous botanists in America and abroad, including the leading authorities on the genus *Pinus*, Bailey came to the conclusion that the Great Basin bristlecones were a hitherto unrecognized species of pine distinct from

Engelmann's *Pinus aristata*. The evidence was overwhelming. He wrote up his findings and published the description of this new species in the *Annals* of the Missouri Botanical Garden, Volume 57, pp. 210-249, 1971. His name for the new species is *Pinus longaeva*. Appropriately *longaeva* means "long-lived", and is the Latin root of the English word "longevity." The type locality is the Wheeler Peak Scenic Area, Humboldt National Forest, White Pine County, Nevada. The holotype specimen is in the herbarium of the University of Colorado. Isotypes are at the Missouri Botanical Garden herbarium and at several other important herbaria.

Here we have a magnificent illustration of the value of herbaria by which we keep the taxonomic fabric of the plant world in order. Without our great collections of preserved plants from the present as well as the past we would not understand how plants are related nor how they evolved. The longest living things known, *Pinus longaeva*, the Great Basin bristlecone pines, whose ages can be precisely determined non-destructively by the techniques of dendrochronology, are of enormous interest to scientists for a variety of reasons.

They are also of an almost mystical fascination to the public whose own maximum life span of 100 years is so very short compared to these trees capable, under certain favorable circumstances, of attaining ages of 5,000 years. Moreover the older and more exposed trees are frequently objects of great beauty to all who contemplatively behold them, and are deserving of the strict protection they are now being given by the U.S. Forest Service in the accessible and exceptionally fine stands of the "Ancient Bristlecone Pine Forest" of California.

Dr. Dana K. Bailey was born at Clarendon Hills, Illinois, on 22 November 1916. His father taught history at La Grange, Illinois. The young Bailey had an exceptional childhood interest in natural history which led him to discover, when only 10 years old, a new gentian, *Gentiana puberula* var. *lilacina*. Dr. Paul C. Standley of the Field Museum in Chicago encouraged the lad to collect and study and helped him identify and name his new discovery. The interaction of the interested layman with the professional scientist was highly significant. It is one of the reasons why the museums and botanical gardens of the world continue today to have professionals who are willing to teach natural history to children and adults.

The Bailey family moved to Riverdale, New York, in 1928, and in the following year death left the young boy without a father at the age of 13. Young Bailey attended the Fieldston School for his high-school studies. For the summer of 1931 his mother sent him to a cattle ranch in central Arizona where his interest in natural history continued to develop. There, for example, he found a rare purple-flowered species of cinquefoil (*Potentilla*) which had not previously been reported from the region. During high-school days at Fieldston he was an avid amateur astonomer and was an officer of the Junior Astronomy Club at the American Museum of Natural History. A

Author photo

The needles of the Great Basin bristlecone *(Pinus longaeva)* are easily dated. The year 1960, indicated by the pen, was a year of low available moisture as can be seen from the very short needles. This photograph was made in June 1969 before the needles of that year had developed.

few years later when Bailey graduated from the University of Arizona, Professor A. E. Douglass made a present to him of his personal copy of William Chauvenet's book *A Manual of Spherical and Practical Astronomy*, a classic work much sought after then before its later reprintings. Interesting to note is that Chauvenet was Professor of Mathematics and Astronomy at Washington University, St. Louis.

In 1937 Bailey went to Oxford University in England as a Rhodes Scholar to continue his education in physics. After receiving his B. A. degree there in 1940 he went to Harvard University for a semester of study in astronomy, and then went to Antarctica to do cosmic-ray research for Professor Serge Korff with whom in the summer of 1937 he had been on a solar eclipse expedition to Peru. World War II began and in September 1941 he went on active duty for the army. He served with the Signal Corps from 1941 to 1946. During nearly eighteen months of this time he was attached to the Royal Air Force and acted as the Air Ministry representative in the Inter-Services Ionosphere Bureau (ISIB) near London. During this period he received his M. A. from Oxford. For the next twenty-one months he was assigned to the War Department where he established the Radio Propagation Unit (later the Radio Propagation Agency). From April 1945 to June 1946 he served in Manila, Leyte, and Tokyo in connection with Signal Corps ionosphere stations. In Tokyo he assisted Japanese scientists in reestablishing a radio research program.

In December 1946, Bailey joined the RAND project at the Douglas Aircraft Company where he worked in the communication and electronics field. In 1948 he joined the National Bureau of Standards and from 1948 to 1950 he was a member of the U.S. Delegation to the Provisional Frequency Board in Geneva, Switzerland, serving as chairman of the propagation working group. Since then he has been a member of numerous U.S. delegations to international conferences and now serves as the International Chairman of Study Group VI (Ionospheric Propagation) of the International Radio Consultative Committee (CCIR) of the International Telecommunications Union.

At present Dr. Bailey is a Consultant to the Space Disturbances Laboratory, a component of the Environmental Research Laboratories of the National Oceanic and Atmospheric Administration

(NOAA), in Boulder, Colorado. He is currently engaged in active research on solar cosmic rays and electron precipitation in the polar regions. For four years he served as the Scientific Director of Page Communications Engineers, Inc. in Washington, D.C., before re-joining that part of the National Bureau of Standards that had moved to Colorado and was subsequently incorporated in NOAA.

Bailey is the author of numerous papers appearing in various scientific journals, and on the basis of these Oxford University awarded him the D. Sc. degree in 1967. His professional affiliations include membership in the American Astronomical Society, the American Geographical Society, the American Geophysical Union; he is a fellow of the American Physical Society, the AAAS, the Royal Geographical Society, and the Royal Astronomical Society. He holds the Legion of Merit and is a member of Phi Beta Kappa. He received the Arthur S. Flemming Government Award in 1951, and has received the U.S. Department of Commerce awards for both meritorious and exceptional service.

Scientific discoveries are made by persistent inquisitive people with good intuition who wish to know the answers to questions they ask. The route to success need not be through formal training, but scientific success requires sustained careful research. Dr. Bailey has never taken a formal course in botany, but then the author of this article has only taken one such course. □

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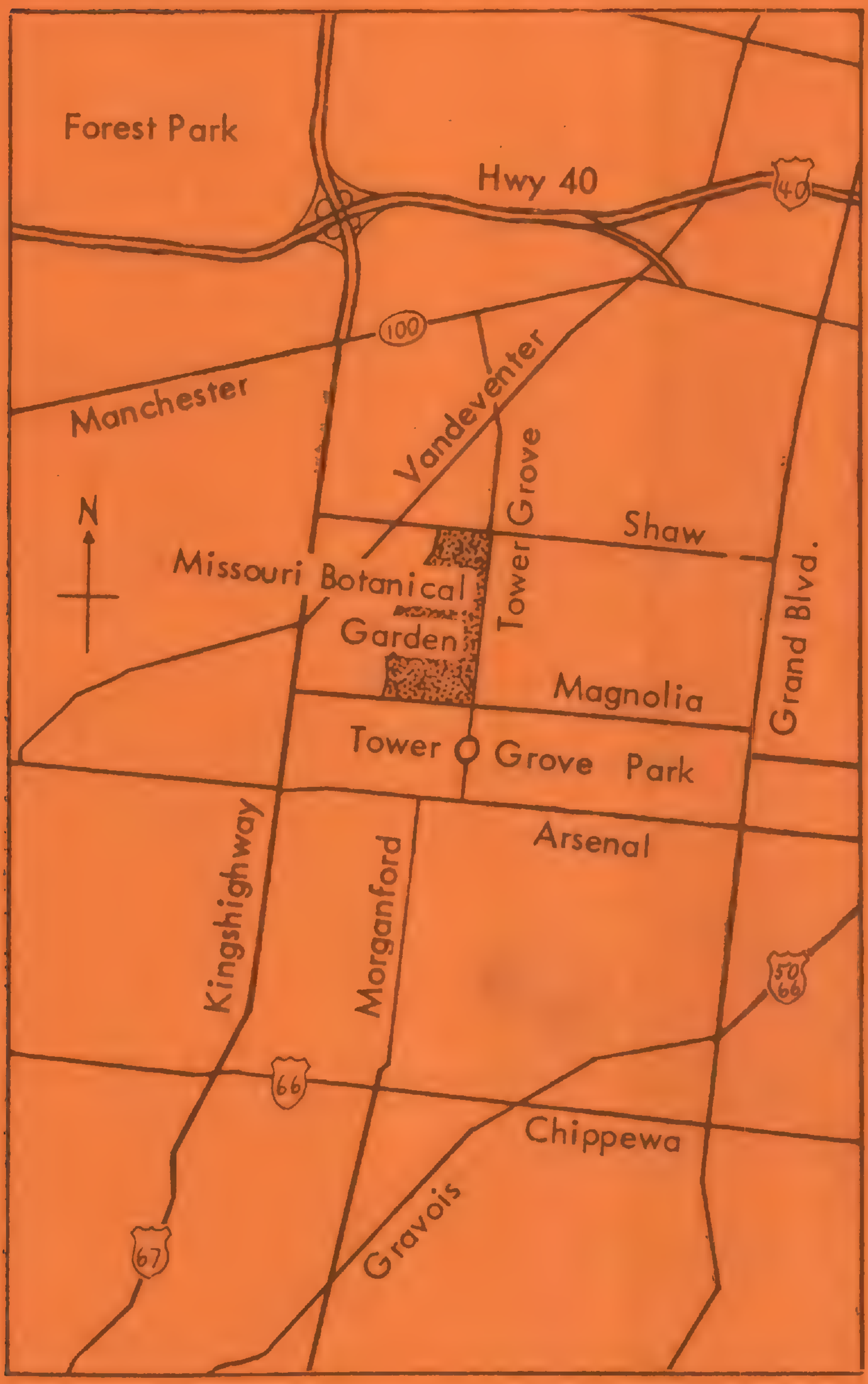

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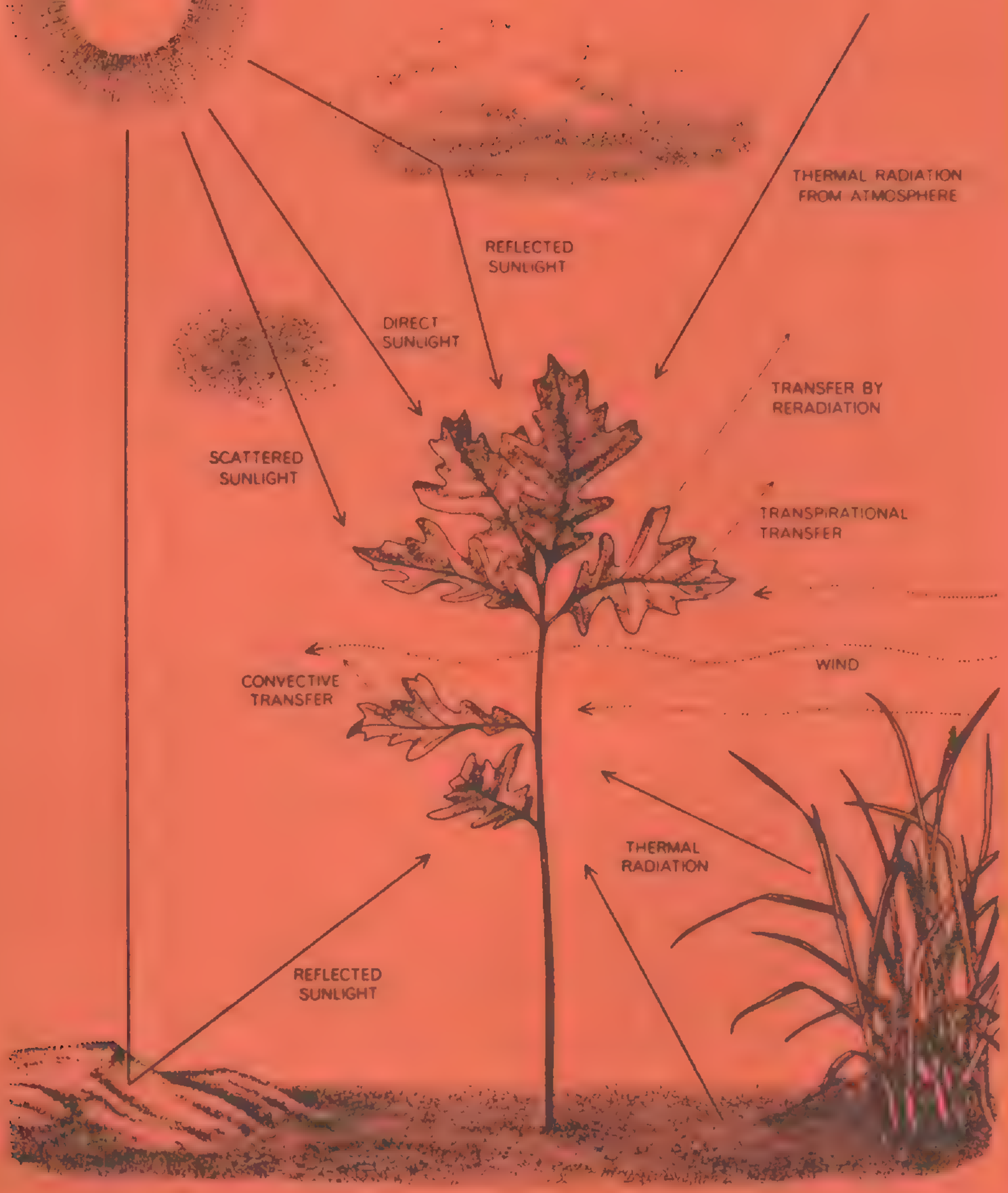

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JULY-AUGUST 1971

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From The Director

SIX YEARS AGO when I came to the Missouri Botanical Garden from the University of Colorado the word ecology was unknown to the general public. Today it is one of the most popular words in our vocabulary. My father, Frank C. Gates, was one of the first ecologists in America, entering the field in 1910 with the publication of a paper on the relic dunes of northern Illinois. For the next 45 years he spent most of his professional life in ecology and plant systematics. During my formative years we knew well most of the leading ecologists of America.

Although I studied some entomology and botany, I majored in physics at the University of Michigan where I did my Ph.D. thesis in molecular spectroscopy. During 15 years of research and teaching in physics and atmospheric physics I often thought about the beautiful and fascinating features of the landscape. I began to wonder exactly how plants and animals interacted with the environment in which they live. I wondered how the wind, water, sunlight, air and soil affected the life of a plant, and how and why the plants and animals of the world lived where they do.

Suddenly I could see that a knowledge of physics was essential to our understanding of ecosystems. Plants and animals exchange energy, gases, chemical nutrients, and water with their environment and the mechanisms of exchange involve the laws of physics. But the

Claude Johnston

The Ecology Group shown here in early 1971, includes, (left to right, front row) Charles Puccia, Sam I. Ajiri, Shmuel Moreshet, E. Lloyd Dunn, David M. Gates, Christa R. Schwintzer, Shirley Barnett, Oscar H. Soule, and (back row) George S. Bakken, Gerald W. Pingel, David Aronow, Jim McCrum, James R. Spotila, S. Elwynn Taylor, Paul W. Lommen. Missing from photograph are Sia Morhardt, LaVerne Papian.

manner of organism response is biological. I blended the knowledge of physics and biology into a new subject now called biophysical ecology. This issue of the *Bulletin* is devoted entirely to a general description of our ideas concerning biophysical ecology, including our laboratory and field work. Many of our readers will gain insight into the elements of the living landscape from the articles written by my young Ph.D. scientific associates. Almost everything contained in this issue represents relatively new understanding of ecology most of which was done during the last few years at the Missouri Botanical Garden.

David M. Gates

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Illustration represents the ecological relationship between a plant and its environment.

(From "Heat Transfer in Plants" by David M. Gates. Copyright © 1965 by Scientific American, Inc. All rights reserved.)

BIOPHYSICAL ECOLOGY

David M. Gates

ECOLOGY IS THE STUDY of the interactions of organisms with their environment and of the interactions of organisms with one another. By definition, in order to do the science of ecology well, one must thoroughly understand the plants or animals with which one is working and understand equally thoroughly the physical environment in which they live. The world about us is a world of heat and cold, light and dark, wind, water, gravity, electricity, magnetism, chemical elements, and all the forces which have shaped the biosphere of our planet.

This is the physical world which is studied by the physicist, chemist, meteorologist, geologist, geophysicist, and others. But ecology is not just the study of the physical environment, it is the study of the manner in which the physical environment impinges on the plants or animals and how they respond to it. A plant or animal is, however, a very complex entity, an entity which has been shaped by millions of years of evolution in response to environmental factors. Generally speaking, the biologist is the scientist who studies living things, but the subject matter is sufficiently diverse and complex that he divides it into many subdisciplines such as taxonomy, systematics, genetics, morphology, anatomy, physiology, molecular and cellular biology, and even more so into various branches of botany and zoology.

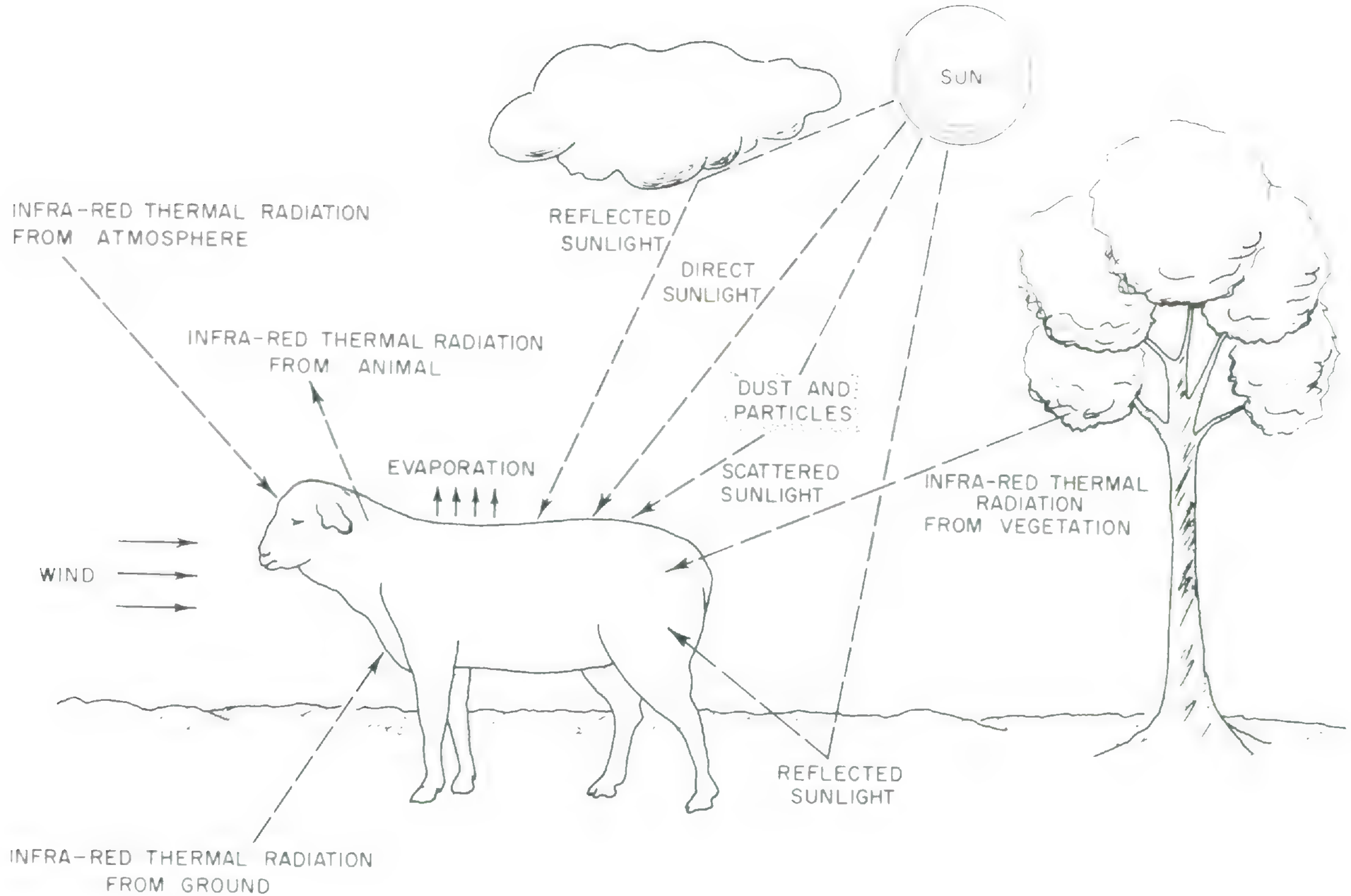
The task of the ecologist is a difficult one. He is the synthesizer and the integrator. He is the person with the overview. He must understand the biotic or biological aspects of the world just as

thoroughly as he understands the abiotic or physical attributes of the environment. This is a difficult accomplishment indeed and in fact our educational system has had a tendency not to encourage this integration of the sciences in the training of a single scientist. We train biologists or we train physicists but we do not often train the complete scientist. It is not sufficient to take one course in physics in order to understand the physical world about us. One must be thoroughly schooled in mechanics, optics, electricity, thermodynamics, atomic and molecular structure, etc. in order to achieve a proper foundation for understanding the forces which shape our lives and the lives of all living things.

At the same time, the ecologist must understand the organisms with which he works. He must know their names, how they are related, where they live, how they function, what their physiological requirements and limitations are, how they reproduce and disperse, and their social behavior and community structure. This is a large order and one, which on the surface, would seem impossible. Does this suggest that the ecologist is simply a jack-of-all-trades and master of none? Does this mean he is perpetually the dilettante? I am convinced that it does not.

There is another pitfall which the ecologist must avoid. While studying physics or chemistry in detail, or meteorology or geology, he must avoid being "captured" by these subjects to the extent he becomes then a physicist, chemist, meteorologist or geologist and forgets his interest in biology. Or to the contrary he cannot become so engrossed with his study of life that he loses interest in the attributes of the physical world. Unfortunately the traditional training of scientists has created the kind of dichotomy which I am insisting we must avoid with the training of ecologists.

It is exciting to be an ecologist. It is challenging and satisfying. The ecologist is truly the complete scientist and his depth of training is in both the physical and biological sciences. It requires more careful planning of curriculum and career and it takes more time. But to avoid doing so is a disaster for the individual whose desire is to do well the science of ecology. For this reason, I have developed the subject called biophysical ecology. The term is redundant, but lends emphasis to the idea that both the biotic and abiotic aspects of the subject matter must be understood thoroughly.



Energy exchange between an animal and the environment.

ECOLOGICAL QUESTIONS

Before I describe biophysical ecology let me say a word about the kinds of ecological questions to which we ultimately need some answers. Why do particular kinds of plants grow where they do in the world? Why are succulents and thorny shrubs found in the deserts? Why do semiarid zone plants such as mesquite, creosote bush, palo verde, and others invariably have small leaves? Why does Gambels oak grow on the drier, warmer lower slopes of our western mountains; Ponderosa pine at intermediate more moist, cooler elevations; spruce and fir further up the mountain; and only grasses and herbs on the tops of our high mountains? Why do we have timberlines and tree limits? Why do pines of various kinds grow all the way from the Gulf of Mexico to the Brooks Range in Alaska? Why do specific kinds of plants grow together, such as the particular mixtures of oak, ash, hickory, walnut, and juniper in our woods of Missouri? Why do cottonwoods and sycamores grow on the flood plains of our rivers? Why does plant succession proceed in the particular way it does in a given habitat? What advantages does a particular plant form have over another form and shape for competition within a given field or forest? Why do some plants thrive in the sun and others do well only in the shade of their neighbors? Why do sunflowers seek disturbed sites where many other kinds of plants find life too difficult? Why do only certain kinds of plants grow in bogs, other kinds along lake shores, some types on sand dunes, other kinds in moist soils, completely different plants in dry soils; and some seek hot climates while still others distinctly prefer the cold? Insects, birds, mammals, reptiles, amphibians, and other animals are distributed throughout the world, but each species is limited in a particular way. But why? Some animals associate only with certain kinds of plants. We wish to know all of these things.

It is my belief that the life of this planet, and for that matter any life anywhere in the universe, is shaped and regulated by the physical forces of its environment; and in turn organisms develop a highly organized complex of responses which produces mutual assistance to one another and helps shape the localized environment of

their habitats. Those organisms which do not evolve in a cooperative, collaborative manner with their fellow travelers get wiped out and those unable to cope with the environmental forces of their habitats do not survive. Therefore in our attempt to understand the incredible diversity and distribution of life on this planet we must understand these forces and know precisely how organisms are coupled to their environment.

The difficulty of achieving this understanding is enormous. There are many dependent and independent variables involved and numerous plant and animal parameters as well. The climate of the environment in which we live is described in terms of sunlight and radiation, wind, precipitation, humidity, and soil moisture, and air temperature. Plants and animals respond to all of these factors by assuming a certain temperature themselves, by having certain rates of water loss, and by building tissue and growing in specific ways. We want to know exactly how all of these things are interrelated.

Plant or animal temperatures, rates of water loss, and photosynthesis or metabolism are dependent variables. There are four or five independent variables, e.g. the environmental factors, and numerous plant or animal parameters which must be specified. We are trying to find our way in a world of seven, eight, or ten dimensions or more. You and I can draw easily a two dimensional graph, or even sketch a three dimensional diagram, but when we get into four or more dimensions we quickly become lost in the vast variability of this complex world. What we need is a compass in order to navigate in this domain of many variables. Mathematics and sound physical principles will help us build the compass we require.

ENERGY EXCHANGE OF PLANTS

All life does work and consumes energy. Without a flow of energy between an organism and its environment, life could not exist. The variables which describe climate, e.g. radiation, air temperature, wind, and humidity, are each different in character but have one feature in common, e.g. energy, with respect to the way they affect an organism. Once we understood that energy was the common denominator for the way climate is coupled to a plant or animal then we were able to establish precisely the effects of climate on any

organism. Basically, all organisms must be in energy balance when considered over extended intervals of time. If we work with this principle and account for all of the energy which flows to or from an organism we can then relate the response of the plant or animal to its climate.

Energy is transferred between a plant and its environment by radiation, convection, evaporation of water, and by chemical reactions. One direct consequence of energy flow to or from a plant is that the plant has a certain temperature and a definite rate of water loss. Just as body temperature is important to each of us so also is the temperature of a leaf important to a plant. The rate at which a leaf carries out photosynthesis is directly dependent upon its temperature. At low temperatures the rate of photosynthesis is is low and at very high temperatures the rate is also low, but over a fairly broad span of optimum temperatures the rate is maximal. Plants which are adapted to very cold conditions, such as aretic or alpine tundra, have evolved maximum rates of photosynthesis at optimum temperatures near 10 or 15°C (50 to 59°F), while those that live in more temperate regions do best at 25 to 30°C (77 to 85°F), and some tropical plants like corn have maximum photosynthesis at nearly 40°C (104°F). Aretic and alpine plants die at temperatures at which tropical plants thrive.

The energy balance of a plant leaf is written as follows:

$$\text{Energy In} = \text{Energy Out}$$

$$\text{Radiation Absorbed} = \text{Radiation Emitted} + \text{Convective Heat Loss} + \text{Evaporative Energy Loss} + \text{Metabolism}$$

This statement concerning the mechanisms which determine the energy flow between a plant leaf and its environment can be given a more detailed description. The radiation absorbed by a plant leaf includes sunlight, skylight, and reflected light, and also includes infrared radiation emitted from the atmosphere towards the ground and from the ground surface towards the sky. A detailed description of these various fluxes of radiation is more than we can give here, but suffice it to say that a leaf always has radiation incident upon its two surfaces and it absorbs a certain fraction of this radiation. A leaf absorbs about 50% of sunlight and skylight and about 97% of infrared thermal radiation. All surfaces emit radiation according to

the fourth power of their absolute surface temperature; in the case of a leaf the radiation emitted is equal to a constant, σ, times $T\ell^4$.

Air flowing over a leaf surface transfers heat at a rate proportional to the difference in temperature between the leaf and the air, and proportional to the square root of the wind speed. If the air is cooler than the leaf it takes away heat, and if it is warmer than the leaf it delivers heat to it. There is, next to every surface, a boundary layer of adhering air across which convective heat transfer occurs. The thicker the boundary layer, the less is the rate of convective heat transfer. A large leaf has a thick boundary layer of adhering air and a small leaf has a small one. It turns out that the boundary layer thickness is proportional to the square root of the width of the leaf, W, and therefore the convective heat transfer is inversely proportional to the square root of the leaf width. If V is the wind speed the total convective heat transfer is written $k(V/W)^{1/2}\ (T\ell - T_a)$ where k is a proportionality constant and T_a is the air temperature.

The rate of moisture loss from a leaf depends upon the availability of energy which is necessary to change water from liquid to vapor within the leaf and upon the existence of a water vapor gradient between the leaf and the air. The water vapor concentration inside the leaf, $M\ell$, is a function of the leaf temperature and is considered to be at saturation. The water vapor concentration of the air is the amount of water vapor the air would contain at saturation, M_a, multiplied by the relative humidity, H, of the air. Water vapor escaping from a leaf must flow from the interior spaces within the leaf mesophyll out through the stomates or pores, across the boundary layer, and into the free air beyond the leaf. This pathway offers a resistance to flow which we call R. The rate of water loss from a leaf, E, which we refer to as the transpiration rate, we write as follows:

$$E = \frac{M\ell - H\ M_a}{R}$$

For every gram of water transpired, approximately 580 calories of energy are consumed. In order to place this term into the energy budget equation we must multiply the rate of water loss by 580.

It is now possible to put all of these terms back into the energy budget relationship in order to visualize how it is that a leaf responds to the energy flow between it and the environment. Hence, if the

amount of radiation absorbed by a leaf is Q, we get in mathematical language for the energy budget the following:

$$Q = \sigma T\ell^4 + k(V/W)^{1/2} (T\ell - T_a) + 580 \frac{M\ell - H\ M_a}{R}$$

Every leaf in the world, in effect, solves this equation for its leaf temperature and rate of water loss every moment of every day of its life. It turns out that the metabolic rate can be ignored in this energy balance as a term which is small compared to the values of the other terms. Now for the first time one can see with precision just how it is that radiation, leaf temperature, relative humidity, and wind simultaneously affect the leaf temperature and the rate of water loss. We can also understand exactly which leaf properties need to be known in order to realize the manner in which a leaf will respond to its environment. The important leaf properties are its ability to absorb radiation, its leaf size or width, W, and the resistance, R, to water loss through the stomates and boundary layer. It is a much too detailed story to relate further here except to give an illustration concerning an observation I made in Australia several years ago.

Near Sydney, in the National Forest, were a variety of trees in close proximity with leaves of very different sizes, shapes, orientations, colors, resistances, and other properties. The summer day was warm, 32°C (89.6°F), the sky was clear except for a deck of high cirrus clouds, and there was little or no air movement. I made observations of plant leaf temperatures during midday when the sun was near the zenith. *Erythrina indica*, a tall tree with large leaves (8 x 10 cm) standing nearly vertical, had temperatures between 36° and 38°C (96.8-100.4°F) for sunlit leaves and at 33°C (91.4°F) for shade leaves. Those leaves which were not upright but in a horizontal position had temperatures 42° to 44°C (107.6°-111.2°F). The vertical leaves of *Erythrina indica* kept cool by assuming a vertical position under the noon sun and thereby not absorbing much solar radiation. Nearby was a cottonwood, *Populus deltoides*, transplanted to Australia from North America. Its large leaves were nearly the same size as those of *Erythrina*, but instead of being vertical they were primarily in a horizontal position. Immediately I thought they would be very warm, but when I pointed my infrared thermometer at them I found the sunlit leaves to be at 32° to 34°C (89.6°-93.2°F)

and the shade leaves at 30°C (86.0°F). The coolness of the shade leaves, which were 2°C (3.6°F) under the air temperature, and the relative coolness of the sunlit leaves immediately told me that this cottonwood was transpiring large amounts of water. These leaves were dissipating the large quantity of absorbed sunlight by turning on evaporative cooling and making abundant use of soil water.

A jacaranda tree, *Jacaranda acutifolia*, with very small leaves exposed to full sun had leaf temperatures not exceeding the air temperature by 3°C (5.4°F). These leaves lost heat rapidly because of strong convective transfer between the leaves and the air. Here among these three kinds of trees I found in operation all three mechanisms for keeping cool. The *Erythrina* kept cool by not absorbing much radiation; the *Populus* used evaporative cooling to consume the heat absorbed from the sun; and the *Jacaranda* had its leaves tightly coupled to the air temperature by having small leaves with large convection coefficients. If none of these mechanisms were used and if the sunlit leaves were large, in a horizontal position and without transpirational cooling, their temperatures would have been about 45°C (113°F) or more. Denaturation of many plant proteins occurs at these temperatures.

PHOTOSYNTHESIS

The next step in our progress towards understanding precisely how a leaf lives in its environment was to analyze the way a leaf takes in carbon dioxide from the air and exactly how the leaf assimilates the carbon dioxide through photosynthesis. The flow of carbon dioxide into a leaf from the air is a gas diffusion process. Once the carbon dioxide reaches the chloroplasts located within the mesophyll cells it enters into a very complex chemical reaction known as photosynthesis. Clearly the rate at which the carbon dioxide diffuses into the cells must be compatible with the rate at which it is assimilated in the chemical reaction. The photosynthetic rate is dependent upon the light intensity, the concentration of carbon dioxide at the chloroplast, and the temperature of the leaf.

We can describe all of these events in mathematical language based on fundamental scientific principles. By combining these processes with a simultaneous solution of the energy budget equation

for a leaf we can predict the photosynthetic response of a leaf to the environmental factors of incident radiation, air temperature, wind speed, and relative humidity. Also we can demonstrate analytically the dependence of photosynthesis by a whole leaf on such leaf properties as absorptivity to radiation, size, shape, orientation, diffusion resistance to water vapor and to carbon dioxide, and to coefficients which describe the chemical capacity of the chloroplasts to respond to light, carbon dioxide concentration, and leaf temperature.

For the first time we have an ability to understand the fundamental photosynthetic response of a plant leaf of specific personality and properties to environmental factors. This analysis is absolutely basic to our understanding of ecological processes in a community of plants.

ENERGY BUDGETS OF ANIMALS

Just as human beings must maintain their body temperatures at approximately 37.0°C (98.6°F) so also all other warm blooded animals, the homeotherms, must keep their body temperatures reasonably close to some preferred value which differs from species to species. Body temperatures of birds are generally from 40.5 to 43.3 C (104.9 to 109.9°F) and 47°C (116.6°F) is lethal. Mammals have body temperatures from 36 to 40°C (96.8 to 104°F) and most mammals die when their deep body temperatures reach 42 to 45°C (107.6 to 113°F) or fall below 15 to 20°C (59 to 68°F). Cold blooded animals, the poikilotherms, can tolerate a great range of body temperatures, with a definite preferred range according to species and according to acclimatization. The critical thermal maximum for turtles and snakes is 40°C (104°F) about 45°C (113°F) for lizards, and between 30 and 40°C (86 and 104°F) for amphibians. Garter snakes have survived temperatures as low as −2°C (28.4°F), but most reptiles cannot withstand temperatures below 0°C (32°F) or slightly above.

The body temperature of an animal is maintained at a particular level by the flow of energy between the animal and its environment. If an animal constantly receives too much energy it will overheat and perish or if it receives too little energy it will undercool and not survive. Just as with plants the flow of energy between an animal and the climate of the air or water surrounding it occurs by the mechanisms of radiation, convection, and evaporation of water. In contrast

with plants, many animals can generate substantial metabolic heat and thermoregulate their body temperatures. Although all animals lose heat through evaporative cooling produced by respiratory water loss only a few animals, such as man, can sweat and keep from overheating for limited lengths of time.

We are interested in the energy budgets of animals for a very particular reason. We believe that the energetics of animals partly determines the climates in which animals must live, but also determines the behavior of an animal within a particular climate. Animals are thermodynamic machines. Each and every kind of animal has particular thermodynamic properties which cause it to live within very specific climates. An animal is white or brown or black and absorbs solar radiation according to its coloration. Some animals have fur or feathers and some do not, some have much fat and some very little fat, and in this way the thermal insulation of animals varies. The size of an animal, in particular its diameter, determines the magnitude of the convective heat transfer coefficient. The body temperature of a small animal tends to be much more strongly coupled to the air temperature than does that of a large animal. In fact, for lack of effective convective heat transfer, very large animals such as an elephant or rhinoceros have difficulty preventing overheating when standing in the sun during hot days.

The energy budget of an animal is written in the following mathematical form:

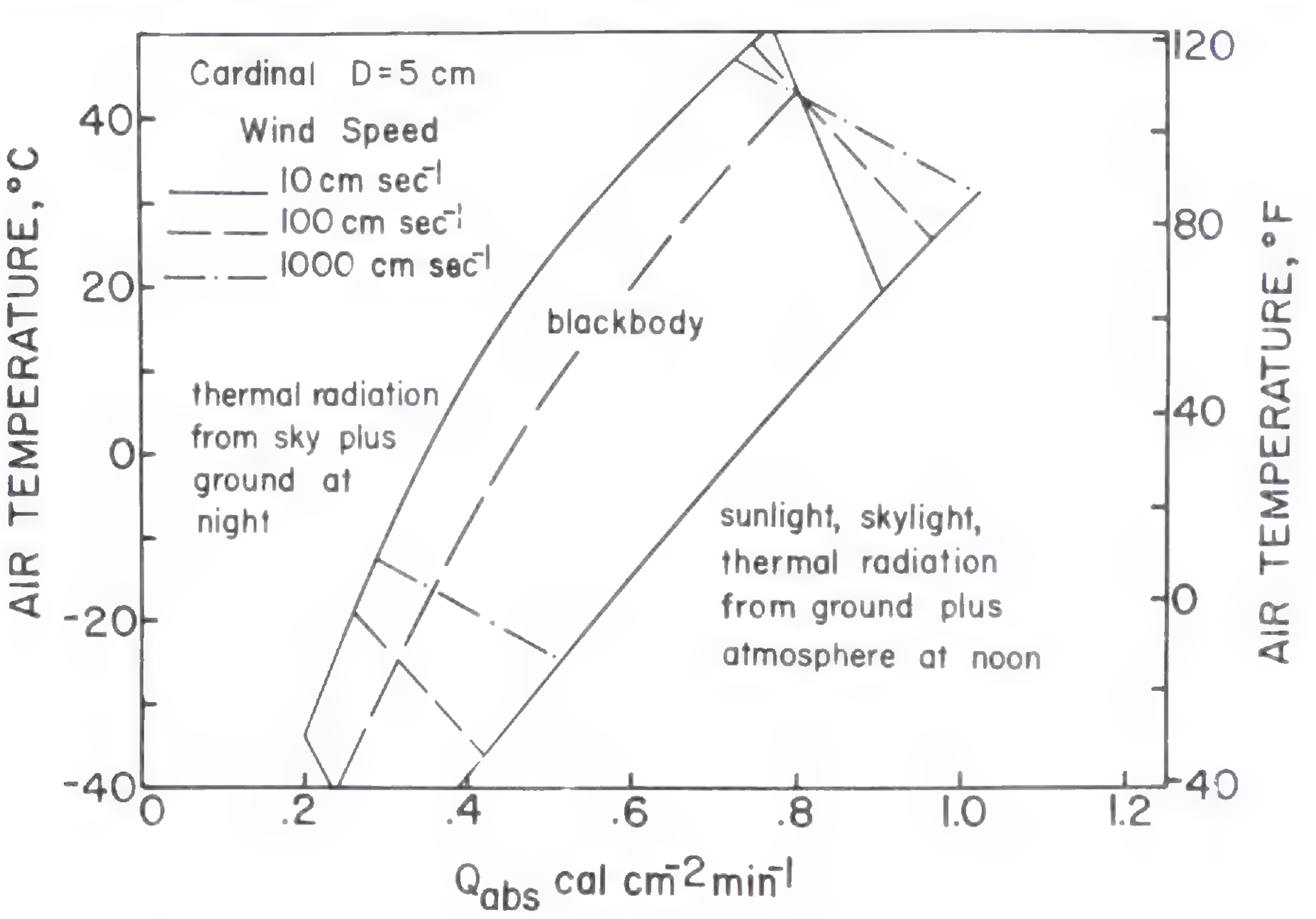
$$\text{Energy In} = \text{Energy Out}$$

$$M + Q = \sigma[T_b - I(M-E)]^4 + k\, V^{1/3}\, D^{-2/3}\, [T_b - T_a - I\,(M-E)] + E$$

This is the balanced energy equation which our own bodies solve every day of our lives. The body temperature is T_b. M is the metabolic heat generated by our furnace. Q is the amount of radiation which we absorb by our surfaces. σ is a proportionality constant for blackbody radiation. I is the thermal insulation created by fur, feathers, fat, or clothing. E is the amount of evaporative water loss, usually respiratory. V is the wind speed and T_a is the air temperature. D is the diameter of the animal's body. k is a proportionality coefficient in the convective heat exchange. A warm blooded animal can vary, I, M, and E in order to maintain its body temperature constant according to the available amounts of sunshine, wind speed and air temperature.

An adult human has a metabolic rate of approximately 150 watts. A person out-of-doors in cool air may lose too much body heat and therefore will put on a coat in order to increase the amount of thermal insulation. By increasing I the quantity $T_b - I(M - E)$ entering the right hand side of the equation is made smaller and the result is a reduction of heat loss due to radiation and convection. The same effect is achieved by increasing the metabolic rate M. If on the other hand a person becomes overheated, say by standing in the hot sun, then he must contrive to dump more body heat by radiation and convection. The quantity $T_b - I(M - E)$ must be increased in order to lose more energy. This is increased by decreasing I, that is taking off an insulating layer of clothing, by decreasing M, or by increasing E, which is accomplished by sweating.

In order to predict the climate in which an animal must live as a result of having specific body properties we put into the equation the values of T_b, M, I, and E which are characteristic of the animal and solve for the set of climate conditions involving Q, T_a, and V. If we allow the animal to change the values of T_b, M, I, and E according to the degree of stress by heat or cold then we obtain the



Climate diagram for a cardinal showing relationship between the bird and air temperature, radiation absorption, and wind speed.

full span of climate conditions within which he must live. We have worked this out for the following animals: white desert iguana, masked shrew, chipmunk, zebra finch, cardinal, sheep, pig, and jack rabbit.

An example of a climate space diagram is shown for the cardinal. The right hand line is the maximum amount of radiation the cardinal would absorb at noon in full sunshine as a function of the air temperature. The left hand line is the amount of radiation a cardinal would absorb at night when exposed to a clear night sky. The physiological limits to the climate space are given by the dashed lines each of which depends upon the amount of wind. The cardinal can occupy any climate which falls within the quadrilateral defined by the right and left hand boundaries and the appropriate pair of dashed lines delimiting either end of the box. The cardinal can withstand very cold winter temperatures, down to −40°C (−40°F), when in still air but in wind can only sustain about −20°C (−4°F). When in full sunshine a cardinal in still air cannot have an air temperature greater than about 20°C (68°F) but with slight air movement (100 cm sec^{-1}) can withstand an air temperature of 33°C (91.4°F). However, in deep shade the cardinal can survive air temperatures up to 46°C (114.8°F). Any bird will always seek habitats which do not endanger its survival by getting too close to its thermal limit.

THE FUTURE

Through our analytical biophysical approach to ecology, based upon fundamental mechanisms and sound scientific principles, we are beginning to understand primary productivity by plants and the behavior and distributions of animals in the world. This may seem like a long and endless procedure for reaching our ultimate goal of understanding entire plant and animal communities. However, I am convinced that this approach is essential if we are ever to understand such things as competition, succession, distribution, density, etc. involving the plants and animals of ecosystems. We have only just begun this complex task and must systematically assemble the pieces of the enormous fabric of life which nature has woven through a billion years of evolution. □

PHOTOSYNTHESIS STUDIES

E. Lloyd Dunn, Paul W. Lommen, Gerald W. Pingel

PLANT PHOTOSYNTHESIS, or the process of using light energy (from Greek *photo*-light) to make food (from Latin *suntithenai*—to put together) is the basic metabolic process that allows life to exist on earth. All forms of life depend on the organic compounds and oxygen produced by photosynthesis in green plants. In its simplest form, this process is described by the following equation:

$$CO_2 + 2H_2O \xrightarrow[\text{chlorophyll}]{\text{light}} (CH_2O) + O_2 + H_2O$$

Basically a plant captures light energy with its chlorophyll pigments, splits water molecules with this energy and combines the hydrogen molecules with the inorganic gas molecule carbon dioxide to produce simple sugars. The oxygen from the water molecules is released as a by-product of the reaction. Water loss as transpiration occurs with CO_2 uptake during photosynthesis since both processes occur through the same diffusion pathway.

Since both photosynthesis and transpiration are such fundamental processes, plants have evolved many structural and metabolic adaptations in response to different environmental stresses. In order to study these basic adaptations of plants to their environments, our group has taken two approaches. One approach is the

actual experimental measurement of rates of CO_2 uptake and water loss in plants from different habitats in order to describe how plants are adapted to different environments. The other approach is to look at the rates of gas exchange analytically and to describe these basic processes in the form of a mathematical model, in order to develop a more precise and predictive understanding of these processes.

In addition to an understanding of evolution in natural plant communities, these studies also provide very important information to more applied fields such as agriculture and horticulture. The interactions of photosynthesis, respiration, and transpiration are the major determinants in plant growth and thus plant production.

The mathematical model is based on knowledge concerning fundamental processes, but it must contain basic information derived from experiments and its predictions must be confirmed or denied by observations. Our goal is to use the mathematical model to predict the rate of photosynthesis of various plants in response to a variety of conditions.

MODEL DESCRIPTION

There are many reasons for constructing or developing a mathematical analysis or model of a phenomenon one wishes to study, just as there are many reasons for constructing models of bridges, buildings, or machines about to be built.

The first reason which comes to mind is convenience. It is a concise way to describe something. An architect's three dimensional model of a building to be built is a very concise way to describe quite accurately how the finished structure will look. It's much more concise than a sheaf of drawings and columns of numbers and lists of materials. Likewise, a mathematical expression, i.e. an equation, can say in a single line what otherwise might take several sentences and/or several figures. Another reason for constructing a mathematical model or description of photosynthesis involves precision. The only way to precisely describe photosynthesis (or any other natural phenomenon) is with the language of mathematics. A third reason is that a mathematical model can be used for prediction of unobserved events.

A mathematical description forces one to sort through all that is known about those aspects of photosynthesis in which one is interested and rigorously assemble the pieces of the puzzle. Once this is done it is often more evident which pieces of the puzzle must be filled in, to complete the picture. Thus, by this point in the model building business, a full circle has come around. The first step is gathering experimetal results which suggest a model or analysis. The analysis may suggest further experiments which may in turn indicate an adjustment or change in the model which may suggest still more experiments and so on. Finally, one should emerge from the analysis and experimenting with a self-consistent description of the phenomenon.

When this stage of development of a model is reached, i.e. when the analysis appears to be a good description of the phenomenon, then it can be used as a useful tool for predicting results for environments not yet tested and for explaining other phenomena.

Our photosynthesis model (See "A model describing photosynthesis in terms of gas diffusion and enzyme kinetics," Lommen, Schwintzer, Yocum, and Gates, *Planta, Berl.*, 98:195-210,1971.) combines three simple ideas. These ideas are: 1) the transporting of carbon dioxide CO_2 in the leaf by photosynthesis, 3) the pathway, or network of pathways along which CO_2 diffuses and is consumed.

It is diffusion and not the flow of air which accounts for the transporting of CO_2 into a leaf. The air is still inside a leaf, throughout the stomates and within the leaf's boundary layer. There is a great deal of motion on the molecular level however, and it is this molecular motion which accounts for the process of diffusion. The basic idea is that if there is a larger concentration of CO_2 outside the leaf than inside the concentrations will tend to become equalized by the random mixing motion of the molecules of the air. The inequality of CO_2 is due to its consumption in the process of photosynthesis within the leaf. For our purposes, the process of diffusion is adequately described by Fick's Diffusion Law:

$$\text{Diffusive flow} = \frac{C_2 - C_1}{R} \qquad (1)$$

This law says that the diffusive flow of a gas, CO_2 in our case, between two points is proportional to the difference in concentration between those two points. The proportionality constant depends on the shape of the pathway involved and is called the resistance of the pathway. Thus if we know the concentrations of CO_2 at various key points inside the leaf and the diffusive resistances along the pathways between these points we can calculate the amount of CO_2 diffusing along each pathway.

The second main idea in our model is the actual consumption of CO_2. This is the process of photosynthesis and is biochemical. The biochemistry, as mentioned before, is extremely compliicated and has not been completely worked out. The mathematical description we use to describe this process is quite simple.

In a photosynthesizing leaf, if only a very small amount of CO_2 reaches the chloroplasts every second, then it is all consumed as soon as it arrives and there will be essentially no CO_2 inside the leaf. Under normal conditions, i.e. when the air outside a leaf has about 0.03% CO_2, the leaf is photosynthesizing at about half capacity and the concentration inside the leaf is about half normal atmospheric concentration. This forces the CO_2 into the processing machinery at the same rate it is diffusing into the leaf. Finally, to get the leaf to operate at full capacity, i.e. to saturate the photosynthetic machinery inside the leaf with CO_2, we must surround the outside of the leaf with a very high concentration of CO_2 (air containing 1 to 2% CO_2 will do).

The mathematical relationship which describes this phenomenon is called the Michaelis-Menton equation, which is shown below:

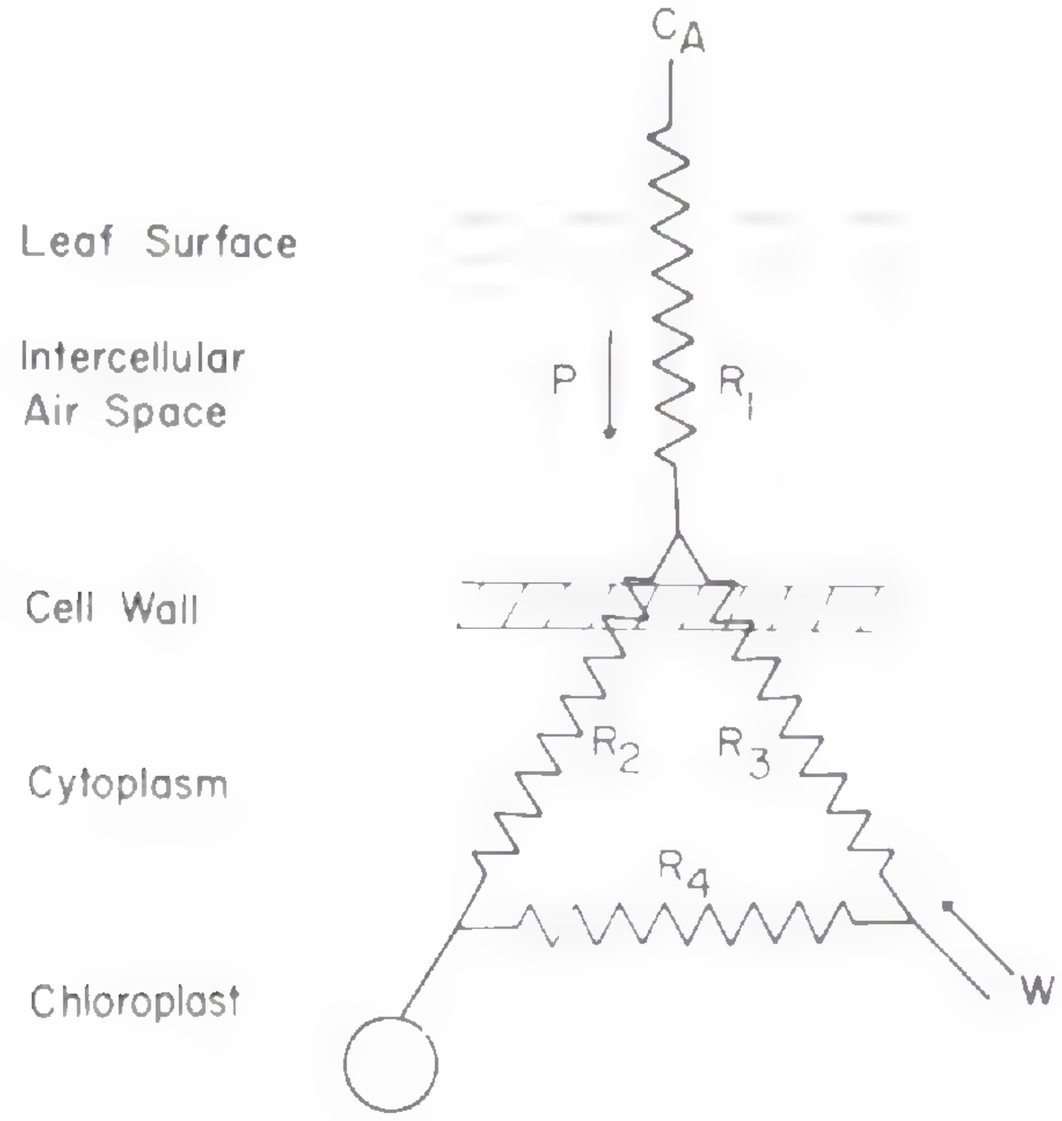
$$P = \frac{P_m}{1 + \frac{K}{C_c}} \tag{2}$$

The symbols in this equation are:

- P the rate of photosynthesis,
- C_c the CO_2 concentration at the chloroplasts,
- K a constant for a particular plant and a measure of how fast the plant can reach its maximum photosynthesis rate,
- P_m the rate of photosynthesis reached at very large CO_2 concentrations.

Equation 2 and the paragraph preceding it provide a good example of how concise an equation can be, as mentioned earlier.

The third main idea in our model concerns the network of pathways along which the CO_2 diffuses, is generated (by respiration) and is consumed (by photosynthesis). This network is shown below schematically.



Resistances R_2, R_3, and R_4 represent diffusive pathways entirely inside the leaf. These resistances are due to cell walls and liquid parts of the cell and are referred to as mesophyll resistances. Resistance R_1 represents the resistance from the intercellular air spaces out through the stomates and boundary layer resistances into the normal air outside the leaf. This resistance is found in the same pathway encountered by water vapor in the process of transpiration. (Its value is 60% larger than the water vapor resistance because the molecular weight of CO_2 is larger than the molecular weight of water.) It can be seen, for example, that CO_2 generated in respiration, W, can diffuse to the outside air through resistances R_3 and R_1 or to the chloroplasts through R_3 and R_2 or simply along R_4. Also CO_2 from the outside air can reach the chloroplasts by either of the paths R_1, R_3, R_4 or R_1, R_2.

It is possible to combine these three ideas just mentioned. The approach used in combining them is that the net amount of CO_2 diffusing into the leaf equals the difference between the amount consumed in photosynthesis and generated in respiration. At the same time, we require that the concentrations at the ends of each of the

resistances be such that the diffusive flow in each be consistent with the net diffusion of CO_2. The equation obtained by this procedure is simply a quadratic equation of the form

$$y = a\,x^2 + bx + c$$

which is the first encountered in high school algebra. Its solutions are of the familiar form

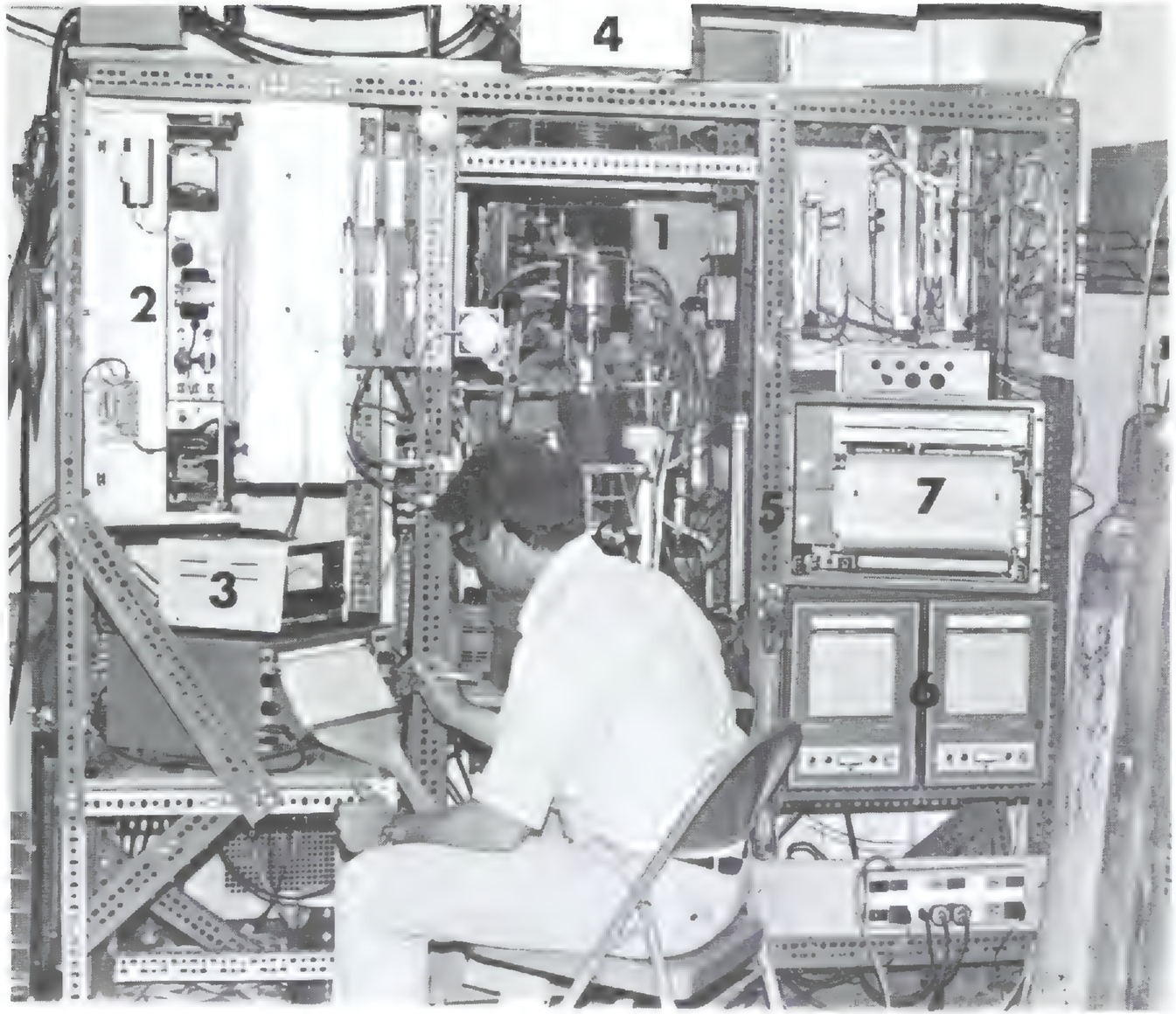
$$x = \frac{-b \pm \sqrt{b^2 - 4a\,c}}{2\,a}$$

The solution of our equation is

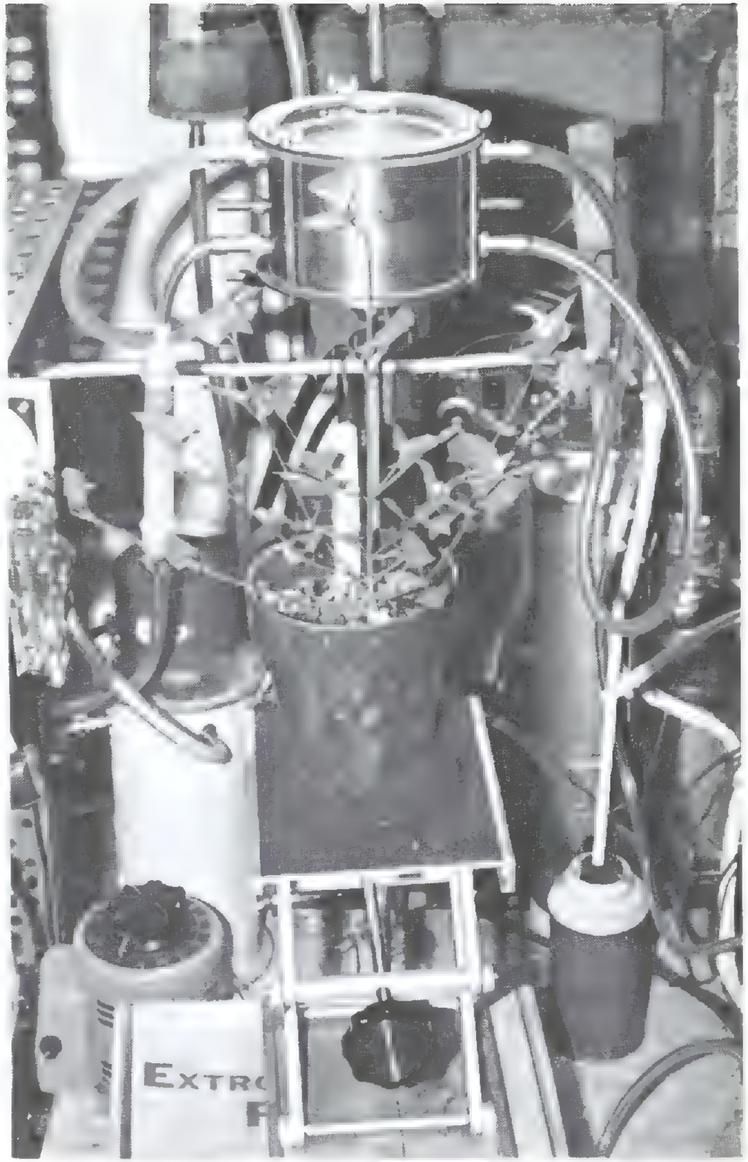
$$P = \left[[C_a + K + S_1(P_m - W) - W\,S_2] - \{[C_a + K + S_1(P_m - W) - W\,S_2]^2 - 4\,S_1[C_a - W\,S_2)\,(P_m - W) - W\,K\}]^{1/2}\right] / 2\,S_1$$

where C_a is the air concentration of CO_2, W is the rate of respiration and S_1 and S_2 are each combinations of R_1, R_2, R_3 and R_4. It is obviously more complicated but the form is the same. If one puts into this equation values for C_a, the R's, W and the biochemical parameters P_m and K, one can then calculate the value of photosynthesis expected. Our desk-top computer, about the size of a large electric typewriter, can do the calculation in about 10 seconds. If we have many values to calculate we use a large computer, which is then more convenient and can do each calculation in about 1/100 second.

We have now described the basic mathematical model. It is true, however, that both the actual model we use and real, live plants are more complicated. For example, P_m, the maximum possible rate of photosynthesis, depends on light intensity and temperature. The parameter K may depend on temperature, oxygen concentration, and CO_2 concentration. Finally, R_1, which is mainly determined by stomatal aperture, depends on light intensity, temperature, water supply, endogenous rhythms as well as depending on its recent history with respect to the above variables. The control a plant has over its stomatal opening is an extremely important way of adapting to environmental conditions. Thus, although a diffusive resistance depending on light, temperature, water, and past history seems very complicated, it is important to understand the various relationships since they are vital to the plant's adaptation and often to its very survival.



Dr. Dunn working with the experimental apparatus to measure rates of carbon dioxide and water vapor exchange from plant leaves. (1) Leaf chamber; (2) CO_2 analyzer; (3) Dew point hygrometer; (4) Xenon light source; (5) Flowmeters; (6) Temperature and humidity controllers; (7) Multipoint recorder.



A close-up of the leaf chamber.

Because the photosynthesis of a leaf depends on light intensity and leaf temperature through R_1, P_m and perhaps K, the photosynthesis model described above can be combined with the leaf energy budget which also depends on light intensity and air temperature, and gives leaf temperature as a result. Therefore it is possible to simultaneously determine photosynthesis and transpiration for a leaf and thereby determine its efficiency of growth. In arid lands, for example, the relation between photosynthesis and transpiration is extremely important since water is so scarce. Perhaps with the use of the combined models, ways will be found to significantly decrease transpiration without seriously affecting photosynthesis (perhaps by decreasing light intensity or increasing relative humidity, for example). In less harsh climates, where water is more abundant, the efficiency of plant growth may still have far-reaching effects on the success of a particular species.

EXPERIMENTAL APPARATUS

Since we are trying to understand the basic plant adaptations and responses to environmental conditions, it was necessary to construct a system in which all of these environmental factors such as light, temperature, humidity and CO_2 concentration, could be controlled and changed independently while measuring the plant responses of CO_2 uptake and water loss. (Photo on page 23) The heart of this system is a completely "air conditioned" chamber in which a single leaf (or by changing the size of the chamber a branch or whole plant) can be enclosed. A small fan provides air circulation and heat exchange for the temperature control system. The temperature of the leaf is measured by a thermocouple sensor held to the underside of the leaf. This input signal goes to an elaborate and sensitive controller which acts as a small computer and determines precisely how much heating or cooling is necessary to keep the leaf temperature at our desired value.

Simultaneously, another control system senses the humidity of the air stream entering the plant chamber and computes another control function to maintain the desired humidity. With our present equipment, we can control the dew point and leaf temperatures to within 0.25°C (0.45°F).

The light source for the small leaf chamber is a 2200 watt high pressure Xenon lamp which provides a light intensity approximately twice that of full sunlight. This light also matches the spectral quality of sunlight, so it is the best artificial source presently available.

The carbon dioxide and oxygen concentration entering the chamber is controlled by mixing gases from large cylinders. This mixture then passes through our humidity control system which adjusts its relative humidity. Then the air of desired CO_2, O_2 and water vapor concentration passes through a very accurate flowmeter to measure the quantity of gas entering the chamber. After this air passes over the leaf surface we can measure the change in concentration of CO_2 and water vapor, which then gives us a measure of the rates of photosynthesis and transpiration. An infrared gas analyzer is used to very accurately measure the changes in CO_2. With this instrument, differences as small as one part CO_2 per million parts (ppm) of air can be detected.

The amount of water vapor added by the plant leaf is measured with a dew point hygrometer, an instrument that chills the air to the dew point and then measures the temperature at which dew just begins to form. With this instrument, water vapor can be measured to within a dew point temperature of 0.2°C.

Finally all of these measurements are sensed by one multi-point recorder which can sample 24 points at the rate of 1 2/3 seconds per point. Obviously a lot of data can be gathered very rapidly when the whole system is operating.

From all of this data, we can determine the basic responses of photosynthesis and transpiration. These measurements provide quantitative comparisons of plant responses from different environments in order to better understand the evolutionary processes that have shaped the structure of natural plants and plant communities. These data also provide inputs to the mathematical model of photosynthesis in order to refine it and make our predictions more precise. In addition this data provide valuable fundamental information for plant breeders, crop scientists, and others interested in plant growth and production. □

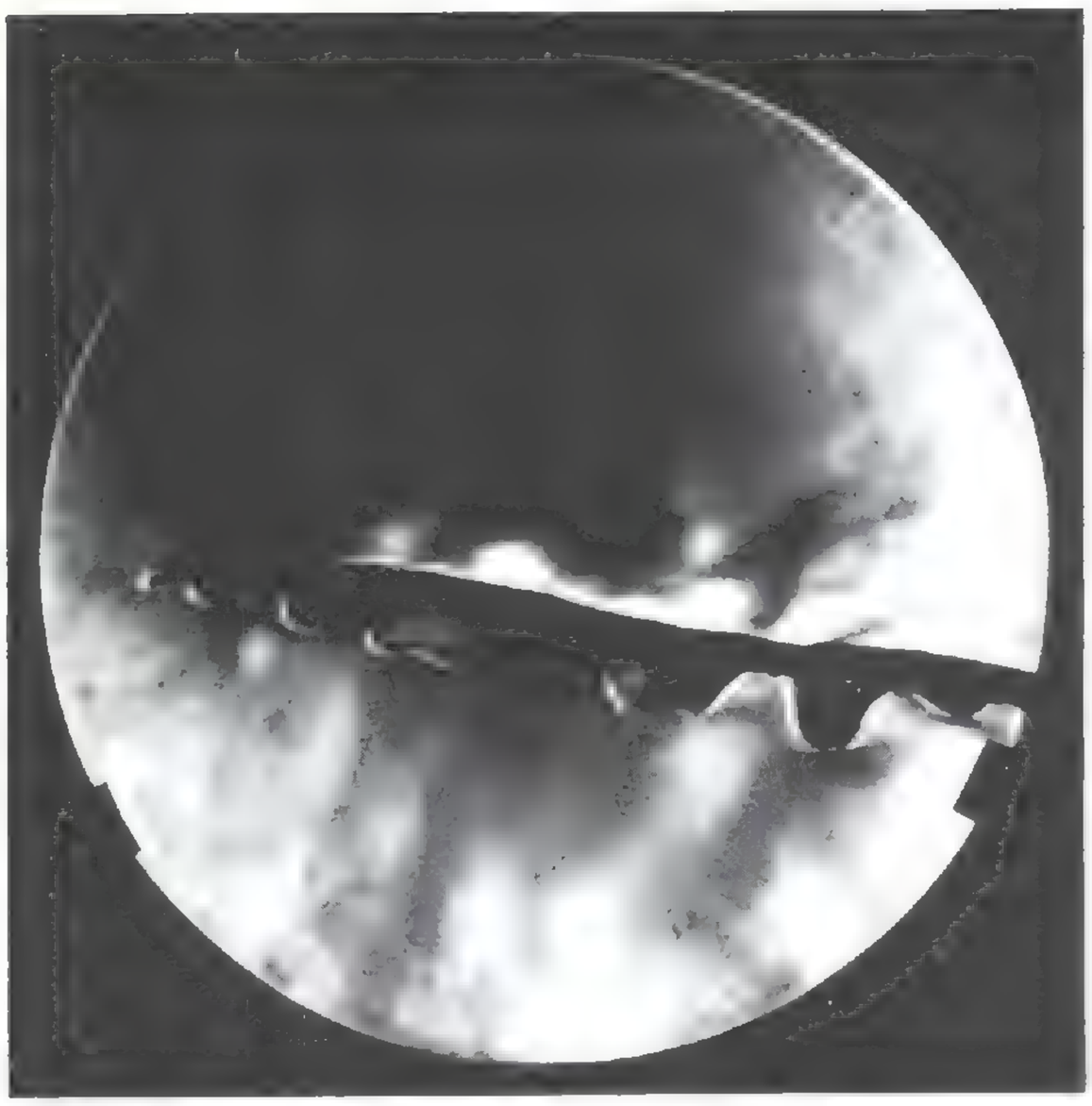
BOUNDARY LAYER ON LEAVES

Samuel I. Ajiri and David M. Gates

WHEREVER A FLUID passes over a solid object, there develops in the fluid a thin zone within which the fluid velocity increases from the solid surface outward. This transition zone is known as the boundary layer. Inside it, the solid influences the intermediate values of velocity, temperature, and moisture or other gaseous concentration. The velocity is zero at the solid-fluid interface and increases to the value of the average mainstream velocity, beyond the boundary layer. The thickness of the boundary layer is defined as the distance from the surface at which the velocity reaches 99 percent of the mainstream velocity. This is known as the hydrodynamic boundary thickness, which distinguishes it from thermal boundary thickness and concentration boundary thickness. Correspondingly, thermal boundary thickness and concentration boundary thickness are the distances from the solid-fluid surface at which the temperature and gas concentration reach 99 percent of the average mainstream temperature and gas content. Beyond the boundary layer the solid ceases to influence the fluid.

The boundary layer is a sort of buffer zone or resistance between the object and its environment. Thus, the thicker it is, the greater the protection an object receives from its environment. Both living and non-living objects derive great benefits from the presence of this protective layer. Man's ability to enjoy a hot Finnish sauna bath without being burned by relatively dry air at well over 100°C is a dramatic demonstration of the protective nature of the boundary layer. The thick fur coat on many Arctic animals not only traps insulating pockets of air within the fur but may also enhance the boundary, hence protective, layer over the animal. In general, it has been found that a hairy leaf has a thick boundary layer over it and is less likely to wilt, from loss of water in the hot sun as is an identical leaf without hairs. In high speed flight, aerospace engineers have for many years protected rocket surfaces from high temperature gas streams by releasing a relatively cool fluid from the rocket surface into its boundary layer.

The theory and applications of the boundary layer have been recognized by engineers and physicists since 1904. It was, however,



The boundary layer over a bur oak leaf (*Quercus macrocarpa*) is revelaed in a schlieren photograph of air flow over the leaf. Its thickness increases as a function of the distance from the leaf tip (left). Farther away from the tip along the leaf surface, the laminar boundary layer becomes quite turbulent. Increased convective activity results and causes a more rapid exchange of transpired water vapor from the leaf to the air. A similar layer (not shown) exists on the lower side of the leaf.

not until about 25 years ago that biologists began applying the knowledge to understand the exchange mechanism of energy and matter between living organisms and their environment. The flow rate of energy or moisture between the plant leaf and the fluid (air or water) surrounding it is proportional to the driving force and inversely proportional to the total resistance. For energy flow, the driving force is simply the temperature difference between the leaf and the air. The driving force for gases (water vapor, carbon dioxide, sulphur dioxide, turpenes, and oxygen) which make their way into or out of the leaf is the concentration difference between the gas in the air and its concentration in the leaf. The total leaf resistance is made up of the internal leaf resistance and the boundary layer resistance. To transfer large quantities of energy or matter rapidly between a leaf and its environment we must attempt to reduce the boundary layer thickness as much as possible by increasing the velocity or turbulence of the medium.

Plants are the earth's principal energy exchangers. Their leaves are the workshops that convert absorbed energy into chemical energy through photosynthesis. The boundary layer through which the nutrients pass should be better understood and possibly controlled to minimize the exchange of pollutants which can endanger the harmonious co-existence of man and other living things on this planet. □

WATER-USE BY BOG SHRUBS

Christa R. Schwintzer and Shmuel Moreshet

Bogs form in cool, moist climates where the land is low and drains poorly. A bog usually begins to form at the edge of a small lake and gradually fills in the lake until no open water remains. The successional growth of a bog begins with aquatic vegetation of the open water which is replaced in order by a floating mat, a grounded mat, and a bog forest. The floating mat consists of a dense mass of floating vegetation strong enough to support the weight of a man. The grounded mat is similar except that the free water beneath it has been replaced by organic materials.

Evergreen shrubs of the heather family (Ericaceae) are found on the floating mat and in the bog forest but they are especially common on the grounded mat. Leather-leaf (*Chamaedaphne calyculata*) is the most numerous. Others include Labrador-tea (*Ledum groenlandicum*), bog-rosemary (*Andromeda glaucophylla*), bog-laurel (*Kalmia polifolia*), and cranberry (*Vaccinium oxycoccus*). Several other species including pitcher-plant (*Sarracenia purpurea*), sundew (*Drosera rotundifolia*), blueberries (*Vaccinium* spp.), and several kinds of orchids are commonly associated with the evergreen shrubs. Bog soil has a thick surface layer of peat moss (*Sphagnum* spp.), the soil itself being made up of organic material in various stages of decay. It is water-logged, acidic, and deficient in essential minerals especially nitrogen and potassium.

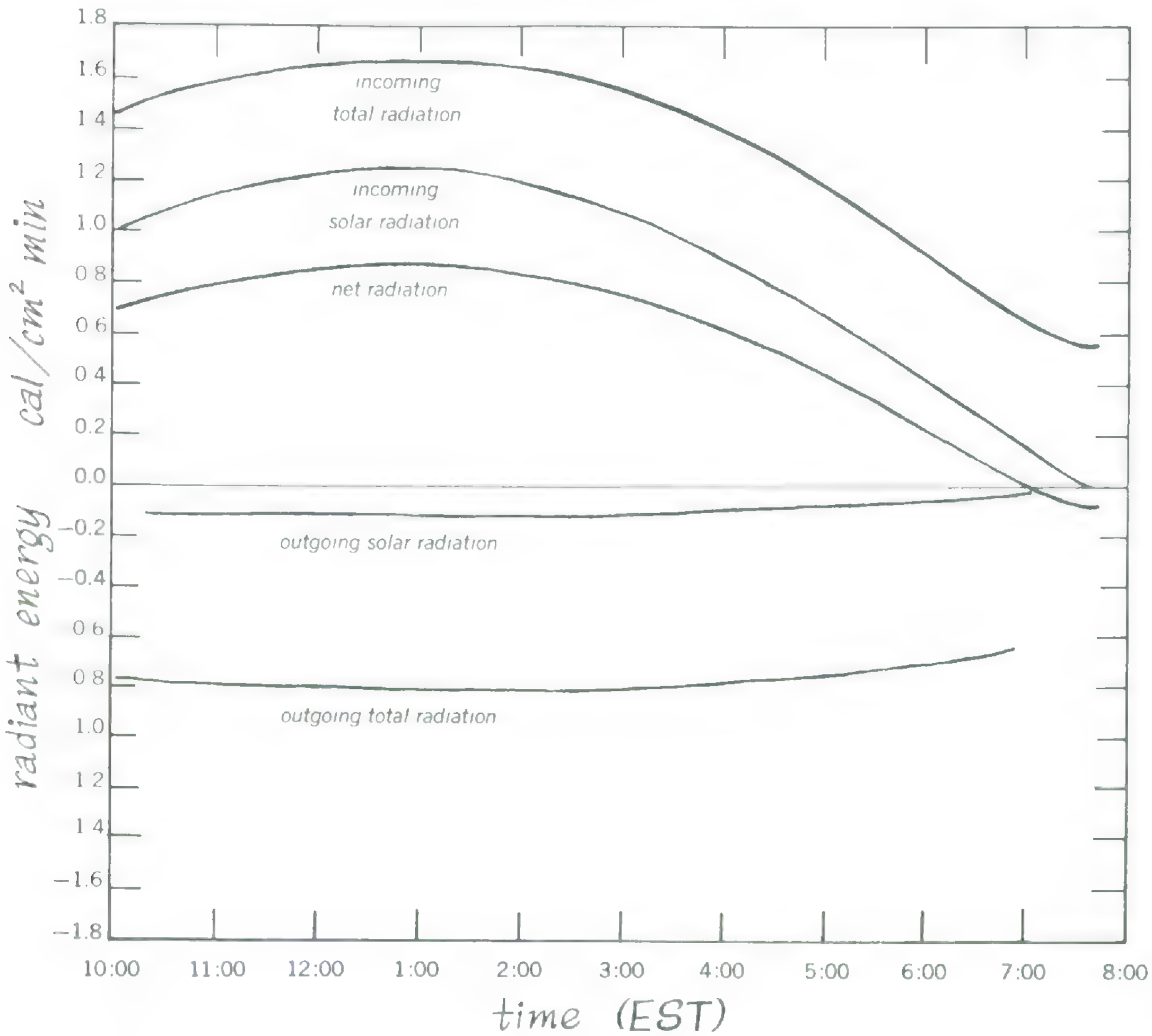
Dr. Shmuel Moreshet preparing to measure leaf resistance to water vapor diffusion at our study site at the northern edge of Mud Lake Bog in northern lower Michigan. Note the small, almost vertical leaves on the leather-leaf bushes making up most of the vegetation in the foreground. The trees in the background are part of the upland vegetation at the edge of the bog.

The leaves of all of the evergreen shrubs are small, thick, more or less upright, covered with a thick cuticle, and similar in appearance to the leaves of plants growing in very dry areas. Leaves with these characteristics have been called xeromorphic (dry-form) and are generally assumed to be adapted to conserving water. Even though there is plenty of water in the bog it has been suggested that the plants cannot obtain it and hence live under conditions of "physiological drought."

Since water-use by plants is governed by their physical environment as well as their structure, detailed information about their physical environment is needed to evaluate this theory. Therefore we studied the physical environment of the evergreen shrubs on the northern edge of Mud Lake Bog in northern lower Michigan in the summer of 1970. The study area and some of our equipment are shown in the photograph. When walking through this area at midday in late July one first notices that the bog is very peaceful and beautiful as only undisturbed areas can be. One then becomes aware

of the heat of the sun shining down on the waist high shrubs, the yellow-green color of the nitrogen-starved bog plants in sharp contrast to the bluish-green of the nearby upland forest, unbelievably large numbers of ripe blueberries, and the resilient, wet soil underfoot. The fragile nature of the bog soon becomes painfully obvious in the broken branches of the bog shrubs and the slushy, ankle-deep puddles that replace the peat moss and upper soil layers wherever someone walks even four or five times.

We measured incoming and outgoing solar radiation (visible light plus short-wave infrared radiation from the sun), incoming and outgoing total radiation (solar radiation plus long-wave infrared radiation from the ground and the atmosphere), air temperature, leaf temperatures, humidity, soil temperatures at various depths,



Total radiation, solar radiation, and net radiation above a dense stand of leatherleaf bushes at Mud Lake Bog in northern lower Michigan on July 22, 1970.

wind speed, and the rate of water loss by leather-leaf twigs. These measurements required a large amount of equipment, some of it expensive and delicate. Everything had to be carried into the bog by hand. Some things could be stored in large plastic bags in the bog between observations, but many instruments had to be carried in and out each time.

We needed perfectly clear days in order to have the constant conditions required for some of the measurements and to be able to get a clear picture of changes throughout the day. On several days we carried all our equipment into the bog, set it up, and began our observations only to discover fluffy white clouds on the horizon which quickly moved overhead spoiling the experiment. After several false starts, we got some good cloudless days, and with the help of Leslie Towill, a graduate student in botany at The University of Michigan, set up the instruments and recorded the necessary measurements.

The results from July 22, 1970 are representative of bog conditions on clear summer days. Measurements were made at intervals between 10 a.m. and 7:30 p.m. As can be seen in the figure, the amount of incoming solar radiation increased from 10 a.m. when it was 1.02 cal/cm^2 min (calories per square centimeter of horizontal surface per minute) until 1 p.m. when it was 1.23 cal/cm^2 min and then decreased throughout the afternoon until shortly after sunset when it was too small to be measured. The curve for incoming total radiation has much the same shape but never goes to zero since the atmosphere always gives off long-wave radiation. The curve for net radiation (the difference between the incoming and outgoing total radiation) follows the solar radiation curve during the day. Near sunset it becomes negative and remains negative throughout the night. During the day when the net radiation is positive more energy is added to the vegetation by radiation than is lost by radiation. This excess energy evaporates water in the leaves and the soil surface and warms the plants, air and soil. Consequently the curves for the air, leaf, and soil surface temperatures all have the same general shape as the net radiation curve. The air temperature was 79.0°F at 10:30 a.m., 86.0°F at 1 p.m., and 64.4°F at 7:30 p.m. Leaf temperatures were about 1°F warmer than air temperatures throughout the day. The soil temperature at 1/2 inch below the surface was 82.0°F at 10:30 a.m., 91.7°F at 1 p.m., and 66.0°F at 7:30 p.m. Soil temperatures were lower further beneath the surface

and had less variation than at 1/2 inch below the surface. At 10 inches below the surface the temperature remained constant at 59°F throughout the day. The relative humidity was 43% at 10:30 a.m., 37% at 1 p.m., and 82% at 7:30 p.m.

We were surprised to find the relative humidity so low since the wet bog soil supplies large amounts of water for evaporation. Relatively low humidity combined with high net radiation favors high rates of water loss by plants. However, even under these conditions, water loss can be kept at a low level by high diffusion resistances to water loss in the leaves (see the article on water use in dry climates in this issue). If the xeromorphic features of the leaves are adaptations to reduce water loss they should lead to high diffusion resistances and relatively low rates of water loss even when the water supply of the leaves is unlimited. Instead of this expectation, the measured diffusion resistances were low and the measured rate of water loss high. These results indicate that the plants use large amounts of water and obviously are able to get it from the soil. Consequently we can conclude that the plants are not under "physiological drought" and the xeromorphic features are not an adaptation to a shortage of water. Dr. Frank C. Gates, an eminent plant ecologist who spent many summers studying the Michigan bogs, has suggested that the xeromorphic features may be an adaptation to winter conditions. Since these plants are evergreen, the leaves continue to be exposed to conditions favoring some water loss during the winter when the soil is frozen and water uptake is difficult if not impossible. Another possible explanation is that the so called xeromorphic features are not adaptations to reduce water loss at all but are a response to some other environmental factor.

Obviously more experimental work will have to be done before we can fully understand the adaptive significance of the xeromorphic leaf characteristics of bog evergreens. The results of our study show that the evergreen bog shrubs are not suffering from "physiological drought" and that extreme caution must be used in forming conclusions about functional adaptations on the basis of morphological features. □

Water Loss and Plant Growth in Dry Climates

Shmuel Moreshet and Christa R. Schwintzer

Water is a very important factor in arid and semiarid zone agriculture since its amount is generally limited and competition for it is intense. Several methods of conserving water and increasing the efficiency of its use by plants have been suggested. In order to evaluate these methods, we must understand how plants use water and how water use is related to photosynthesis, the uptake of carbon dioxide and its conversion to carbohydrates.

Plants take up water from the soil through the roots. It then passes up through the stem to the leaves. Water evaporates from the walls of the cells in the leaf into the air spaces between the cells and diffuses out of the leaf into the atmosphere through the stomates, special pores in the leaf surface which can change their size. In addition, a relatively small amount of water evaporates directly from the leaf epidermis through the cuticle, a waxy covering on the outside of the leaf. The amount of water which is lost by the leaves is controlled by the environment both directly and also indirectly through its effect on the stomates. The environmental factors affecting water loss are the amount of energy absorbed by the leaves, air temperature, humidity, and wind speed. In addition, the plant controls the rate of water loss by changing the stomatal width. The wider the stomatal opening, the higher will be the rate of water loss. The width of the stomates depends mainly on light intensity,

but many other factors also affect it, including soil moisture, leaf temperature, and wind speed. The interaction of these factors and others not mentioned here, control the rate of water loss from plants.

Water loss from plants is primarily a physical process and is governed by the laws of diffusion. Carbon dioxide, on the other hand, is taken up by the leaves from the atmosphere by diffusion through the stomates and is then converted into carbohydrates by enzymes in the chloroplasts inside the leaf cells. The production of carbohydrates is a chemical process and its rate is primarily controlled by the light intensity and the leaf temperature. Diffusion of carbon dioxide into the leaf at any given atmospheric concentration depends on the width of the stomates and the wind speed. It is governed by the same laws of diffusion involved in the loss of water vapor from the leaves. While ninety nine percent of the water which is transported through the plant is lost to the atmosphere, about eighty percent of the carbon dioxide which is fixed in the leaves remains in the plant and is used for growth and reproduction. In other words the higher the uptake of carbon dioxide, the higher will be the growth and the yield.

Although most of the water taken up is lost, plants cannot grow without it. Since the overall processes of water loss and carbon dioxide uptake share the diffusion path from the atmosphere through the stomates to the cell walls, but are not otherwise the same, it is possible that the amount of water lost to the atmosphere could be reduced without causing a significant reduction in growth. An agricultural crop in semiarid zones may use about one million gallons of water per acre per growing season. Even if crops could be grown with only ten per cent less water, significant amounts of water could be made available for other uses.

Scientists suggested long ago that water use by plants can be reduced by changing the physical properties of the plant, either permanently by changing their hereditary makeup or temporarily by imposing changes from the outside. Changes can be imposed from the outside in several ways. Since most of the water vapor leaves the plants by diffusion through the stomates, decreasing the size of the stomatal openings decreases water loss. The size of the stomatal openings can be reduced by spraying certain chemicals on the leaves or by adding carbon dioxide to the atmosphere surrounding the leaf. Other ideas of how to reduce water loss include covering

The diffusion porometer being used to measure the resistance of the upper and lower surfaces of a cucumber leaf. Note the shiny condensing surface is easily seen through the window in the upper cup. The porometer was designed by Drs. Conrad Yocum and Shmuel Moreshet, and built by Gerald Pingel.

the leaves with chemicals which add to the resistance to water vapor diffusion without affecting the size of the stomates, and reducing the amount of energy absorbed by the leaves.

Any change which increases the resistance of the stomates to diffusion of water vapor away from the leaf also increases the resistance to carbon dioxide diffusion into the leaf since both share the same gaseous phase diffusion path from the free air through the stomates to the cell walls. However, carbon dioxide encounters an additional resistance because it must diffuse from the cell walls to the chloroplasts through the liquid inside the cells. This added liquid phase resistance may be fairly large since diffusion through liquids is ten thousand times slower than diffusion through gases such as air.

The effectiveness of reducing water loss by changing the stomatal resistance depends largely on the size of the liquid phase resistance. If it is large compared to the gaseous phase resistance,

reducing the gaseous phase resistance by changing the size of the stomates may reduce water loss more than carbon dioxide uptake. This possibility was tested theoretically using mathematical models for water loss and photosynthetic carbon dioxide uptake developed by Dr. David M. Gates and members of the ecology group. The two models can be used to predict how the rate of water loss will decrease compared with the rate of carbon dioxide uptake when the stomatal resistance is increased, i.e. when the size of the stomates is decreased. It was found that partial or full stomatal closure greatly reduces water loss. However the rate of assimilation is also reduced. The practicality of reducing water loss by decreasing stomatal size depends on the structure of the leaf and the location of the chloroplasts. Unfortunately, it seems that the structure of most crop plants is such that water loss cannot be reduced without greatly reducing yields at the same time.

As mentioned earlier, water loss can also be reduced by changing the environment. One very promising method is to increase the atmospheric concentration of carbon dioxide. Increased carbon dioxide causes partial closure of the stomates thus increasing the diffusion resistance to both water vapor and carbon dioxide. Water loss is considerably reduced but the effect on carbon dioxide uptake is much smaller because the difference between the internal and external carbon dioxide concentrations is increased at the same time that the diffusion resistance is increased. The overall effect on the rate of photosynthesis is small since the increased concentration difference counteracts the effect of the increased resistance. Unfortunately there are not yet any practical methods of changing the carbon dioxide concentration in the field.

We are now working on a theoretical analysis of the relationship between assimilation and water loss in relation to the amount of energy absorbed by the leaf. Changing the amount of energy absorbed by the leaf may be the best solution to the problem, especially when applied in the range of energies where light intensity and leaf temperature do not affect assimilation very much.

An important tool in testing these ideas is a field method for measuring leaf and stomatal resistance to diffusion of water vapor and carbon dioxide. We have developed a field porometer capable of measuring the total resistance of the leaf to water loss. The basic idea is that when any material is cooled below the dew point of the

atmosphere, water will condense on it. If a cold, shiny surface is brought close to a source of water vapor, such as a piece of moist blotter paper, it becomes fogged as water condenses on it. The time required to fog the surface is proportional to the rate of diffusion of water vapor to the surface. The rate of diffusion from the evaporating surface to the condensing surface for any given set of conditions is controlled by the resistance in the path. As the resistance increases, the length of time required for the condensing surface to fog also increases.

The porometer consists of two small cups that can be attached to a leaf, one on each side, as shown in the accompanying photograph. Each cup contains a condensing surface easily visible from the outside and is arranged so that the air inside can be replaced by dry air. The condensing surface is attached to the end of a copper rod which is immersed in a container of crushed ice. Since copper readily conducts heat this arrangement keeps the condensing surface at a constant, cold temperature. When the porometer is used to measure leaf resistance, both cups are first dried by pumping dry air through them. The porometer is then clamped on the leaf and the leaf temperature and the length of time required for each of the condensing surfaces to fog are recorded and compared to a series of calibration curves to obtain the corresponding leaf resistance.

The calibration curves were obtained by measuring the length of time required for the condensing surface to fog when a series of metal plates with known diffusion resistances were placed between the cup and a source of water vapor. Since the rate of evaporation is strongly temperature dependent, separate calibration curves were prepared for different temperatures.

Theoretical analysis like that described in this article, combined with new research tools like the field porometer, can help solve the problems involved in improving crop yields in areas where the water supply is severely limiting. Solution of these problems could appreciably increase the food supply in many parts of the world. □

Leaf Movements in Coral Bean

Christa R. Schwintzer

CORAL BEANS are tropical and subtropical trees and shrubs of the genus *Erythrina* in the bean family (Leguminosae). The flowers are showy, large and generally bright red. They are shaped like the flowers of the ordinary garden bean but are considerably larger. The leaves have three leaflets. Each leaflet is attached to the leaf stalk (petiole) by a special joint (pulvinus). Another pulvinus attaches the leaf stalk to the stem.

The leaves show two kinds of movements, sleep movements (nyctinastic movements) and bright light movements (heliotropic movements). The sleep movements involve a downward movement of the leaflets at dusk and an upward movement at dawn. At dusk the leaflets move downward from their more or less horizontal daytime orientation until they are vertical with their tips pointing downward and their undersides facing inward toward each other. They remain in this position throughout the night and return to the horizontal position at dawn. The bright light movements occur during the day and involve an upward movement and tilting of the leaflets in response to the intensity and angle of the sunlight striking them. The tips of the leaves point either upward or outward.

The movements may be fast enough to just be visible. They are often complete in about twenty minutes but may take much longer. They result from changes in the relative stiffness (turgor) of opposite sides of the pulvinus. Each pulvinus is made up of a central strand of conducting tissue surrounded by several layers of large, thin-walled cells. The leaflet moves when the cells on one side of the pulvinus take up water and become stiff while the cells on the opposite side lose water and become limp. When the leaflets are pointing downward at night, the upper side of the pulvinus is stiff and the lower side limp, when they are horizontal the two sides are equally stiff, and when they are pointing upward the lower side is stiff and the upper side is limp. The leaflet can be tilted at any angle by appropriate changes in the stiffness of various sides of the pulvinus.

The sleep movements are regulated by an endogenous circadian (*circa* = about, *dies* = day) rhythm, light, and temperature. Endogenous rhythms (biological clocks) have been observed in many phenomena. In man they are responsible for the loss of sense of time of day and the discomfort experienced by air travelers when they cross several time zones. In coral beans and other plants with sleep movements, the endogenous rhythm favors the horizontal position during the day and the vertical position at night. The rhythm is internal and continues for several days in the absence of external stimuli. For example, if one of several coral bean plants is moved in the late afternoon from the greenhouse into a completely dark room with constant temperature and humidity, the leaves become vertical as expected; but the next morning, even though kept in darkness, they become horizontal at the same time as the leaves on the plants in the greenhouse. That night they again become vertical and the following day horizontal.

Sleep movements are also influenced by light and temperature. Light and increasing temperatures cause the leaves to become horizontal; darkness and decreasing temperatures cause the leaves to become vertical. In nature the rhythm, light, and temperature changes all favor the horizontal position during the day and the vertical position at night. Under experimental conditions, when opposing stimuli are presented, e.g. light at midnight (light calls for the horizontal position, the rhythm calls for the vertical position),

the orientation is either determined by the strongest stimulus or it is intermediate.

Sleep movements were extensively studied by early botanists. Charles Darwin devotes a large part of his charming book, *The Power of Movement in Plants*, to them. In spite of all of this effort, their adaptive function is still not known. Darwin suggested that sleep movements increase leaf temperatures and hence reduce frost damage on clear nights by reducing the amount of energy lost to the cold sky as radiation. He tested this hypothesis at a time when it was not yet possible to measure leaf temperatures directly by comparing the extent of frost damage in vertical leaves and in leaves held horizontal during the night by pinning them to corks. The horizontal leaves showed more frost damge than the vertical leaves after exposure to clear night skies during light frosts for various lengths of time. Darwin concluded sleep movements significantly reduce frost damage. I repeated Darwin's experiments with modern methods permitting me to measure leaf temperatures and the amount of energy lost to the sky directly. I found that Darwin was right in thinking that the vertical leaves are warmer than the horizontal leaves because they lose less energy as radiation to the cold sky. However, the measured temperature difference between horizontal and vertical leaves is too small to be significant and is found only in the outer leaves which are exposed to the sky. In addition, if Darwin's method of using corks to hold the horizontal leaves is used, the temperature difference between horizontal and vertical leaves is increased because the cork keeps the air from circulating freely around the horizontal leaves. Consequently at least part of Darwin's result was an artifact of his method and his results cannot be used as evidence that sleep movements significantly reduce frost damage.

Several other functions, including reduction of nutrient loss due to leaching, have been suggested. Significant amounts of nutrients, both inorganic and organic compounds, are leached from leaves by rain and dew. The longer the leaves are wet, the more nutrients are lost. The vertical orientation reduces the length of time that the leaves are wet because water drains much more rapidly from vertical leaves. Consequently sleep movements may decrease nutrient loss by leaching at night. This might have considerable importance for the growth of plants in nutrient deficient soils.

A.

B.

C.

Coral bean (*Erythrina* sp.) in three orientations (x 0.27).
The drawings were made from photographs.
A. Sleep position. The leaves assume this position at night.
B. Standard position. The leaves assume this position in moderate sunlight, in shade, and on cloudy days.
C. Bright light position. The leaves assume this position in bright sunlight.

The bright light movements are regulated by the sun's angle and intensity and possibly by the air temperature. The light intensity and direction are detected by the pulvinus as can easily be demonstrated in coral beans. When the pulvinus is shaded with aluminum foil, the leaflet remains horizontal even if the whole leaflet is exposed to very bright sunlight. However, if the leaflet is shaded and the pulvinus exposed the leaflet moves into a bright light position.

In general, the brighter the incident light, the more nearly vertical the leaflets become. In addition, the leaflets tend to rotate until the leaf surface is parallel to the sun's rays. The overall effect of these movements is to greatly reduce the amount of sunlight incident on and absorbed by the sunlit leaves. The shaded leaves remain horizontal since the orientation of each leaflet is individually determined by the light striking its pulvinus.

The effect of the bright light movements on individual leaflets is to decrease the leaf temperature and the rate of water-loss without decreasing the rate of photosynthesis (carbohydrate production) very much. For any given set of conditions the rate of water-loss depends on leaf temperature, which in turn is determined by the amount of sunlight absorbed by the leaf. Water-loss and leaf temperatures increase as the amount of absorbed sunlight increases. Maximum leaf temperatures and water-losses occur at maximum absorbed sunlight. Photosynthesis also increases with increasing sunlight but only until it has reached its maximum value (light saturation). The maximum value in many species is reached at less than half of full sunlight. Consequently at light intensities above this, water-loss continues to increase with increasing sunlight while photosynthesis does not and the efficiency of water-use decreases. In addition, any excess sunlight, *i.e.* light above light saturation, absorbed by one leaf is not available for photosynthesis by other leaves inside the canopy. By constantly adjusting the angle between the leaf surface and the sun's rays, the bright light movements reduce the amount of light absorbed by the outer leaves thus increasing their water-use efficiency. At the same time, the light not absorbed by the outer leaves penetrates to the canopy interior and is available to be used by the inner leaves. Since photosynthesis by these leaves is severely limited by the low light intensities usually found at the canopy interior, this additional light considerably

increases photosynthesis by the inner leaves. This redistribution of light among the outer and inner leaves results in increased photosynthesis by the plant as a whole with little if any increase in whole plant water-use.

Bright light movements also protect the outer leaves from damage due to overheating. This is especially important when air temperatures are high and the additional heating due to absorbed sunlight is likely to raise the leaf temperature above the highest temperature that it can tolerate. Intense sunlight can also cause partial or complete destruction of chlorophyll, the green pigment necessary for photosynthesis. This is easily demonstrated in coral bean by covering part of a horizontal leaf and exposing it to the sun. After several hours the covered part is much darker green than the exposed part.

We can conclude that sleep movements may function to reduce nutrient loss by leaching; and bright light movements function to reduce water-loss, increase the water-use efficiency of photosynthesis, increase photosynthesis by redistributing light in the canopy, reduce damage due to overheating, and reduce the destruction of chlorophyll by intense light. □

Alligators and the Energy Budgets of Large Reptiles

James R. Spotila

Alligators at the Missouri Botanical Garden mark a new phase in the animal research carried out by the biophysical ecology group. Over the past year and a half Dr. Oscar Soule and I have been studying the energy relationships of large animals. This has been an extension of the work Dr. Warren Porter began in 1967 under the direction of Dr. David M. Gates. Since that time much progress has been made in determining the energy budgets of reptiles, birds, and mammals; and defining the climates within which these animals must remain in order to maintain a steady state energy balance. Most of this work has been done on animals no larger than a pig. Our interest has now shifted to the problem of large body size and its effect on the climate requirements of some of the big reptiles.

We have been trying to quantitate the flow of energy into and out of these animals by means of an energy budget equation. In simple form the equation is : ENERGY IN = ENERGY OUT. Each term can be broken down into many parts which then tell us the mechanisms by which the animal takes up and gets rid of heat. For instance, ENERGY OUT is made up primarily of reradiation, which is heat radiated at the surface of an animal, like the heat given off from a household radiator or a light bulb; convection, such as the cooling effect of wind blowing over the surface of the animal; evaporation, which is the loss of heat through the vaporization of water in the lungs and at the skin surface; conduction, which is the transfer of heat by direct contact with an object such as the cold ground; and physical labor.

We began our current study by trying to evaluate the energy exchange of an alligator. In addition to solving the problem of body size, we hoped to provide new information on the ecology of this species. The American alligator (*Alligator mississippiensis*) once roamed over most of the southeastern United States but now is restricted to areas near the Gulf of Mexico, the Okefenokee Swamp and the Everglades. If we are to keep this species from becoming extinct we must have precise information on its environmental requirements in order to insure the maintenance of habitats favorable for its survival.

During the course of this study we constructed climate space diagrams that outline the physical environment within which the alligator must remain in order to survive (Fig. 2). Under a clear night sky (pts A, Fig. 2 A and B) this animal could withstand a minimum air temperature of from 8.0-11.5°C (46-53°F). Under a sunny sky (pt G, Fig. 2 A and pt D, Fig. 2 B) it could survive a

Figure 1. Close up view of an alligator tethered behind the Climatron during an energy budget experiment.

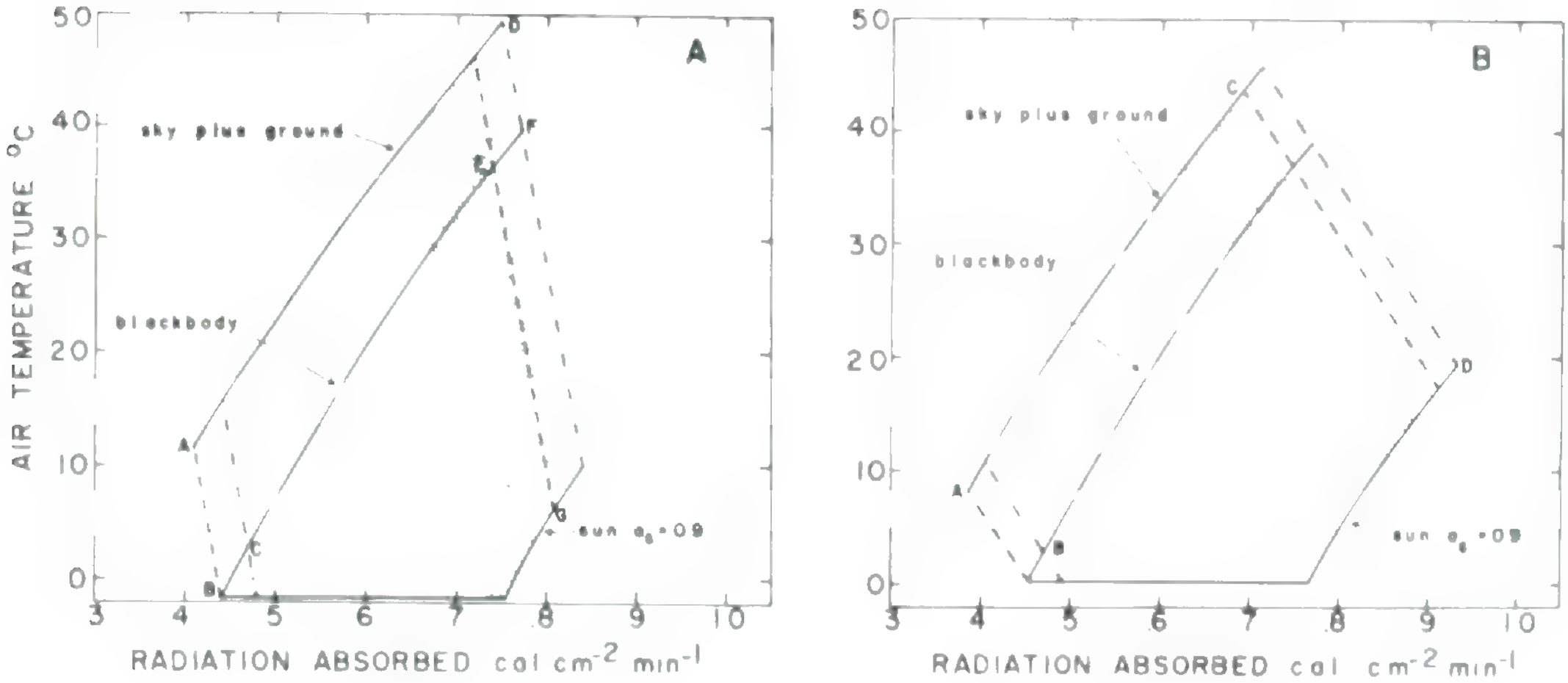


Figure 2. Climate space diagram for an alligator in still air (A) and in a wind of 500 cm sec (11.2 mph) (B) showing the relationships between the air temperature and radiation absorbed. The line marked sun is for an animal in full sun, the blackbody line is for total shade and the sky plus ground line is for an animal at night or in the shade but exposed to a clear sky. The stippled area is the climate space occupied by the alligator at its preferred body temperature, 32-35°C (90-95°F). The dashed lines and dash-dot lines show the effect of conduction when the ground is 3°C warmer or cooler than the body temperature of the alligator.

maximum air temperature from 6.2-19.5°C (43-67°F) and if it was in the shade exposed to a clear sky (pt C, Fig. 2 B and pt D, Fig. 2 A) it could withstand a maximum air temperature of from 43.6-49.2°C (110-121°F). These results indicate that the alligator must remain in the shade or in the water on warm sunny days and on cold nights. It cannot withstand full sunlight for long periods of time or it will overheat and die.

These are very interesting predictions since we usually think of alligators lying along the banks of rivers and lakes exposed to the full sun. To test our ideas we borrowed a 5 ft. alligator from the St. Louis Zoo and tethered it in a small fenced in area behind the Climatron. This space included a portion of a small pool of water. We then monitored its body and skin surface temperatures over a 24 hour period to see if our predictions were correct. Body temperature was measured by inserting an electronic probe into the intestine of the animal, while surface temperature was measured with an infrared thermometer. When it was in the water or in the shade the alligator could maintain a moderate internal temperature (21-24°C; 70-75°F). When we restrained it in the sun with no access

to water its body temperature rose from 22 to 30°C (71.6-86°F) in one hour. This animal was heating up so fast that it probably would have died within 1/2 hour if we had not released it so that it could enter the water and cool off.

Since our predictions were accurate for a live alligator we decided to calculate the energy exchange of a very large reptile. We considered a hypothetical reptile 3 ft. in diameter and 21 ft. long. This would approximate a good sized dinosaur. By giving our model the physical and physiological characteristics of an alligator we were able to predict the environmental limits for such a creature. Our calculations resulted in the climate space diagram in Fig. (3). This reptile would be even more restricted by its physical environment than the alligator. In full sun (Fig. 3, pts A and B) it could withstand a maximum air temperature of from 4.2 to 9.0°C (40-48°F). At night it could survive a minimum air temperature of 17.2-19.4°C (63-67°F) in the open (Fig. 3, pts G and H) and 4.2°C (40°F) if it was in the shade (Fig. 3, pt F) or in water. It would sustain a maximum air temperature of 38.5°C (101°F) if it was in the shade (Fig. 3, pt E).

From this we conclude that large dinosaurs must have been severely limited by their physical environment. They had to remain in the shade during most of the daylight hours. Upland forms prob-

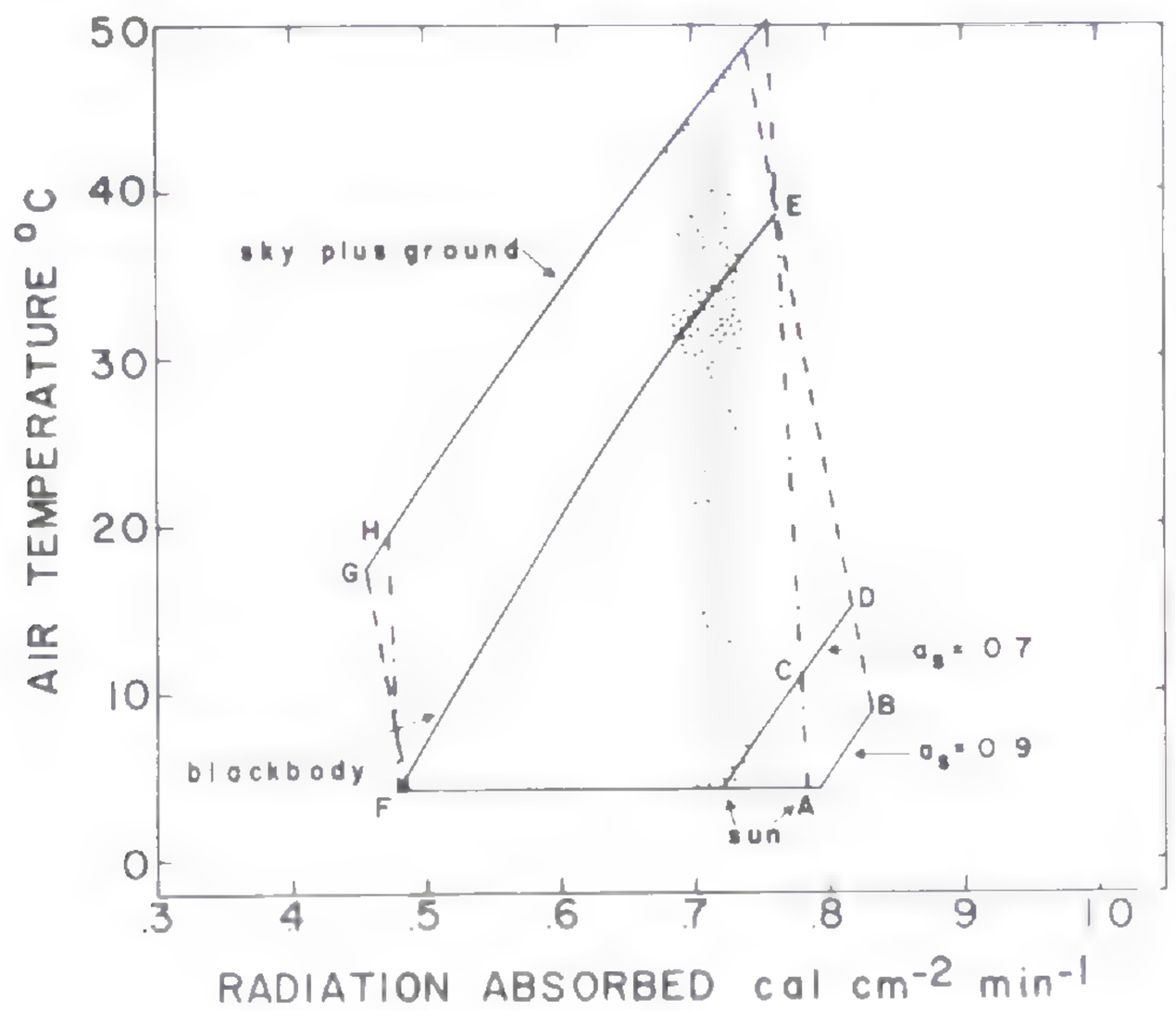


Figure 3. Climate space diagram for a hypothetical large reptile (dinosaur). Explanation the same as in Figure 2. In this case the effect of conduction was neglected The dashed lines are for a wind speed of 500 cm/sec (11.2 mph) and the dash-dot lines are for still air.

ably spent most of their time in the shade while swamp dwellers retreated into the water to avoid extreme environmental conditions.

At present we are continuing our studies on the effect of body size on the physiology of large animals. We hope to be able to prediet metabolic rate (the rate of generation of heat inside the body) and the rate of water loss for different animals based on their physical characteristies alone. We have already shown that there are important differences between small and large animals due to their relative sizes. Small animals are much more affected by wind speed and air temperature than are large ones. Large animals are more affected by the radiation of heat from the sun and their surroundings.

A small animal such as a mouse must dump large amounts of water in order to avoid heat stress under high energy input conditions (high environmental temperatures and large amounts of radiation). Under low energy input conditions it must have a high metabolie rate in order to maintain its energy balance. Large animals are much less affected by such changes in the physical environment. Their large size serves to moderate extreme changes in environmental factors and reduces the demand for rapid changes in their physiological systems.

At this time we are using a large computer at Washington University to aid in our predictions of metabolie rate as a funetion of body size. As our computer model beeomes more preeise and we add more and more environmental and animal properties to it we will have a more accurate picture of what is going on in the real animal world. Eventually we may be able to prediet the optimum size of pigs, cows and other domestie animals so that we can produce more meat at less cost. Animal geneticists can then breed these animals so they are best suited to the particular environment within which they will be raised. In this way cattle raised in Texas will be bred to give maximum meat production in that climate while animals raised in New England will be bred to give maximum production there. Thus by studying the interrelationships of animals and their environment we hope to increase not only our academic knowledge but also our practical knowledge of how animals manage to live where they do.

SURFACE TEMPERATURE OF ANIMALS

A PRELIMINARY LOOK AT VARIATION

Oscar H. Soule

THE SURFACE TEMPERATURE of an animal, which appears in the energy budget equation, controls the heat exchange between the organism and its environment. At times it would be advantageous to have a high surface temperature and at other times a low surface temperature. Organisms with surface temperatures above their immediate environment lose heat and those with surface temperatures below the air or other material with which they are in contact gain heat.

An animal outside of water does not have a uniform surface temperature and differences that do occur often can be interpreted in terms of evolution and adaptation. Many different examples in nature are given to show this. The licking and drooling on body surfaces by mammals when they are hot allows the fur or skin to act as an evaporative cooler. The heat loss through antlers of deer, which will be discussed later, and the countercurrent heat exchange system in various birds and mammals permit the animal to vary the surface temperature of an extremity to facilitate the maintenance of a favorable energy balance with the environment.

Measurements of surface temperature were made at the Saint Louis Zoo on a juvenile, female greater kudu (*Tragelaphus capensis*) (see illustration.) The greater kudu is native to Africa where it grazes on the extensive savannas and grasslands. The kudus are considered to be the most desirable of all the antelopes by the trophy hunters and the big male kudu has been described as one of the most strikingly staturesque of all vertebrate animals. The juvenile female, Pumpkin, used in this investigation had been born and raised at the Saint Louis Zoo and thus was accustomed to being handled.

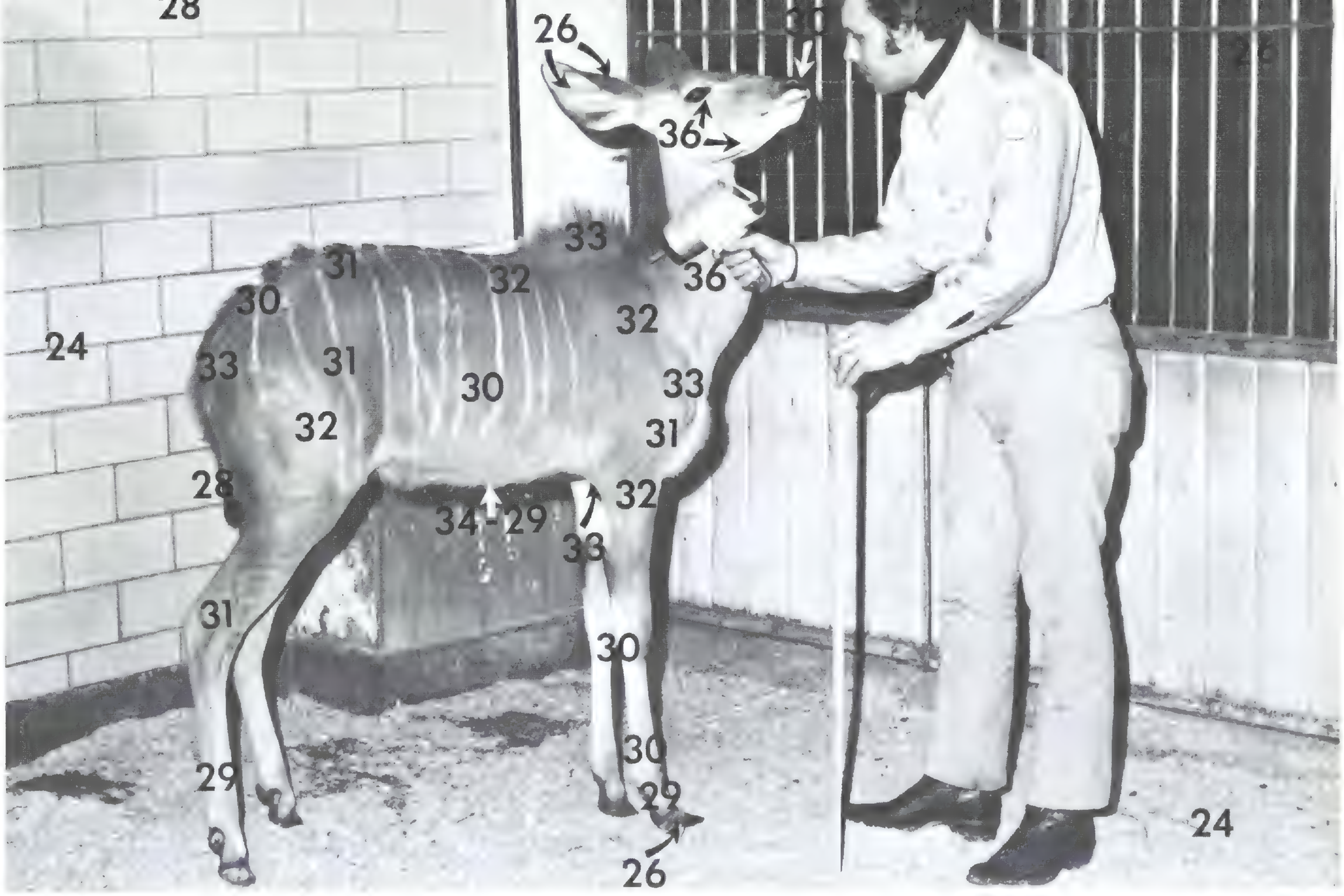
The surface temperatures on Pumpkin varied from 26°C for the hooves and ears to 36°C for the forehead, eyes, cheek, and neck. The surface temperature over the main trunk of the animal was

30-31°C. Over large masses of muscle this increased to 33°C as it did in protected areas such as between the fore legs. Leg temperatures under these non-stress conditions graded from 26°C at the hoof to 32°C or 33°C at the hip and shoulder where large accumulations of muscle produce more heat.

The neck and head regions are of adaptive interest. The main mass of the neck was 33°C; however along the important arteries leading to the head this increased to 36°C. Around the highly vascularized cheek muscles and eye region, the surface temperature was also 36°C. This is nearer the core or deep body temperature of the greater kudu which is approximately 38°C. The nose which was moist had a surface temperature of 30°C, while the ears of the kudu had a surface temperature of 26°C, both inside and out.

This striking difference of 10°C in the few inches between the eye region and the ears represents an important adaptation to survival in harsh environments as well as a good example of energy budget ecology. The flow of blood to the ear is controlled by the kudu. When the environmental temperature is low, or as in this case moderate, a minimal amount of blood passes through the ear giving it a surface temperature like the one illustrated. If the environmental temperature should increase above the thermal neutral or "comfort" zone of the kudu, and its body temperature start to rise, more blood would flow through the vessels in the ear to raise the surface temperature to near the maximum internal body temperature and facilitate heat loss through radiation and convection. The legs also serve in heat exchange in the kudu and other animals. Here as in the ear, a combination of controlled blood flow and countercurrent heat exchange assist the animal in maintaining a favorable energy balance in the environment. The other low surface temperatures on Pumpkin were associated with very long hair hanging away from the body on the rump near the tail and along the mid-ventral line. In this ventral or belly region the surface temperature rose from 29°C to 34°C, as one passed from the long hair to the exposed skin along the natural part in the coat of the kudu.

Pumpkin, as a greater kudu, is a member of the mammalian family Bovidae. This includes among others: the buffalos, bison, cattle, antelopes, goats, and sheep. These animals have horns. Generally both sexes possess these permanent bony structures. The principle component of horn, as well as hair, is a proteinaceous mate-



Surface temperature of a juvenile, female greater kudu (*Tragelaphus capensis*) being taken with a portable infrared thermometer. Air temperature was 22°C with a wind speed of 0 to 0.2 mph. Robert Frueh holding the thermometer and meter stick, is shown here taking readings on Jan. 2, 1970. Wall temperatures were 24° to 28°C and floor surface temperature was 24°C. All readings indicated on photographs are in degrees Centigrade.

rial, keratin. Neither horn nor hair is sensitive to pain nor do they bleed. This lack of vascularization in horns gives them only limited value as avenues of energy exchange.

This is in direct contrast to the Cervidae or deer family, which includes in North America the deer, wapiti (elk), moose, and caribou (reindeer). The males of these species have antlers while the females generally do not. Horn will not regenerate if lost, but antlers are shed and replaced every year. This makes them the fastest growing bone in the body. There is a great deal of similarity between antler growth and malignant bone neoplasm. Also in contrast to horns, antlers have an elaborate system of blood vessels. This can function in heat exchange during the time of antler development from April to August. By August the bony material has fully hardened and the "velvet" which covers the antlers dies and peels off. At this time the antler no longer serves as an organ of heat exchange and is used in the fall mating rituals. However, it is extremely unlikely that antler formation is simply a biological extravagance for this brief period. Instead the more significant value of the antlers to the deer family may be found during the summer months when higher environmental temperatures would be encountered and the antlers could be used as radiative and convective coolers by raising the surface temperatures through peripheral blood flow. Dr. Gates measured the antler temperatures of a red deer in New Zealand and found them to be at 28°C while the body surface temperature was 17°C, the head temperature was 25°C, and the air temperature 15°C. A female reindeer at the Saint Louis Zoo had antler temperatures of 32°C, head 27°C, body 17°C, and air temperature and wall temperature of the shed 15°C.

Surface temperature of animals is an essential item in the fuller understanding of how organisms live in nature. It is the single factor which bridges the gap between the external physical environment and the "milieu interieur" of Claude Bernard. It is also interesting to look at extremities of animals from the standpoint of energy exchange and evolution because here control of surface temperature by the animal contributes greatly to the usefulness of these structures.

Schlieren Photography and the Energy Budget

George Bakken and James R. Spotila

ONE OF THE most important terms in the energy budget equation is convection, a measure of the heat gained or lost by the plant or animal from the air around it. This term is very difficult to study since there are many possible patterns of air flow over the organism. Each pattern brings a different amount of air in contact with the organism adding or carrying off a corresponding amount of heat.

The air flow patterns fall into two classes. In one, air flows over an organism in a smooth streamlined manner called laminar flow. In the other, air flows in an irregular boiling pattern called turbulent flow. Usually they will be combined, with laminar flow where the air first strikes the organism, and turbulent flow farther along the surface. Turbulent flow adds or removes much more heat than laminar flow, so much that we can estimate the amount of heat flow by measuring the thickness of a thin layer of laminar air next to the surface, called the boundary layer. The boundary layer acts like an insulating blanket, reducing the loss (or gain) of heat from the object to the atmosphere. This "blanket" insulates quite as well as a real blanket, as you have no doubt experienced on a warm, still day, and its effectiveness depends on its thickness, just as a real blanket.

Several methods have been developed to examine the flow visually and measure the thickness of the boundary layer. Our work used a technique known as schlieren photography. It is related to a procedure for testing astronomical telescopes developed by 19th century French physicist, J. L. Foucault, Figure 1 shows a drawing of the apparatus. Light from a quartz-iodine projector bulb shines through a slit onto a very precise telescope mirror. The mirror forms an image

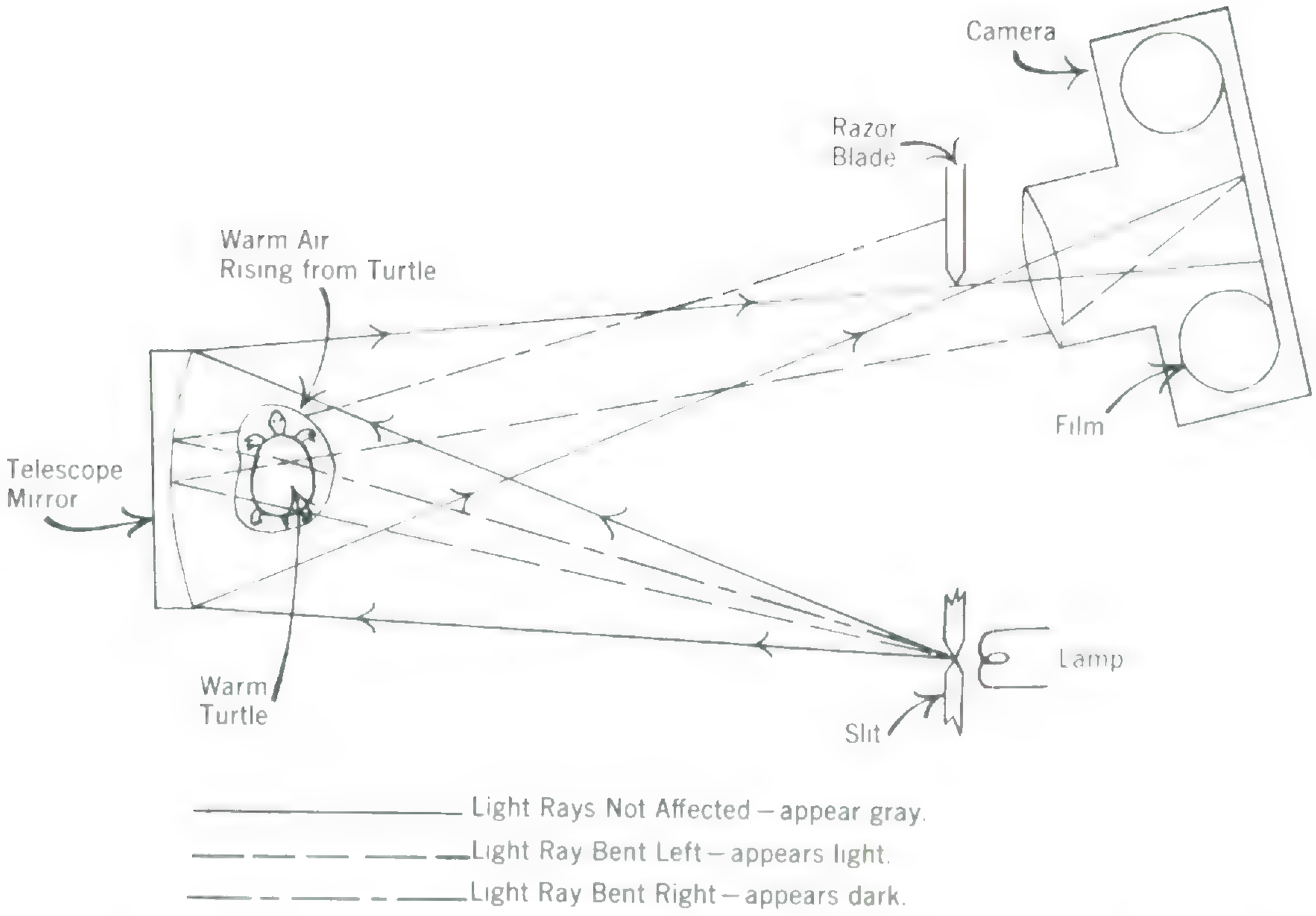
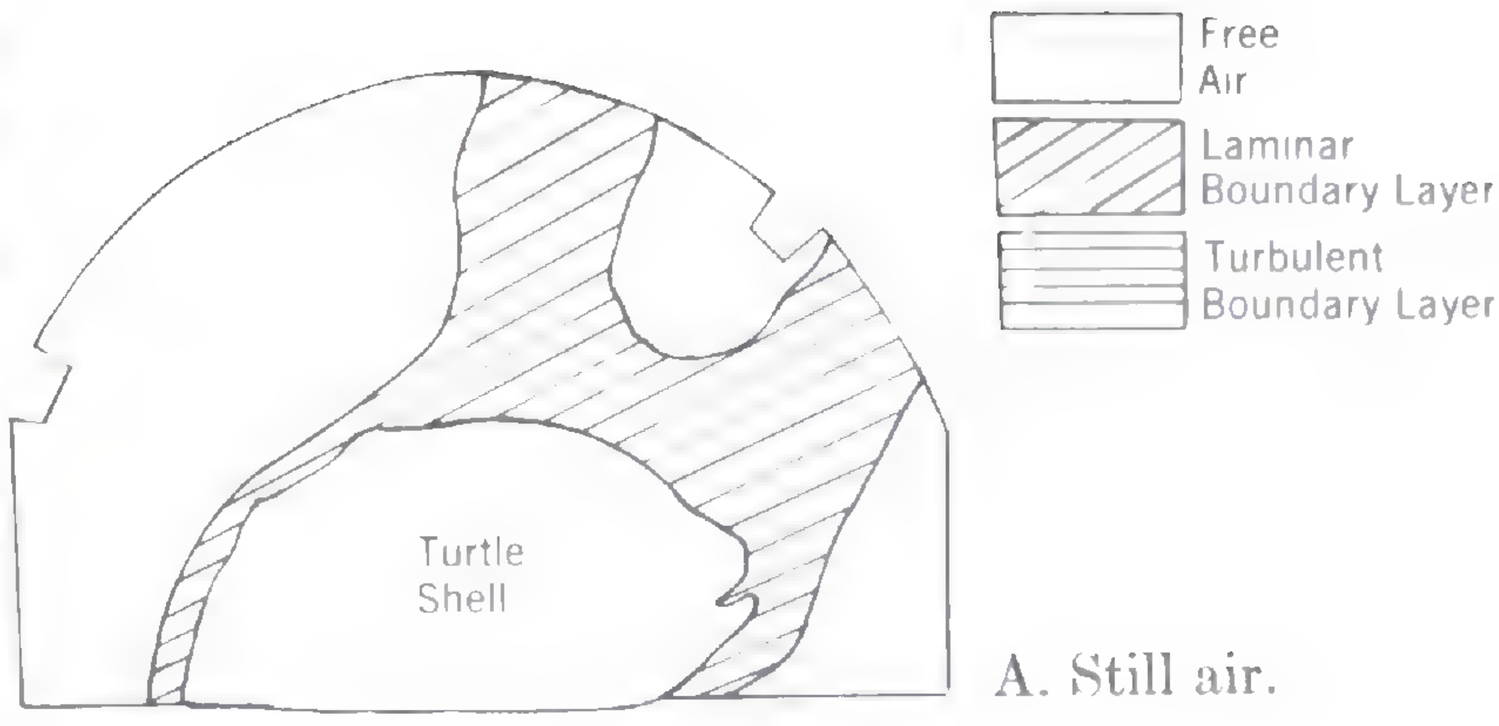


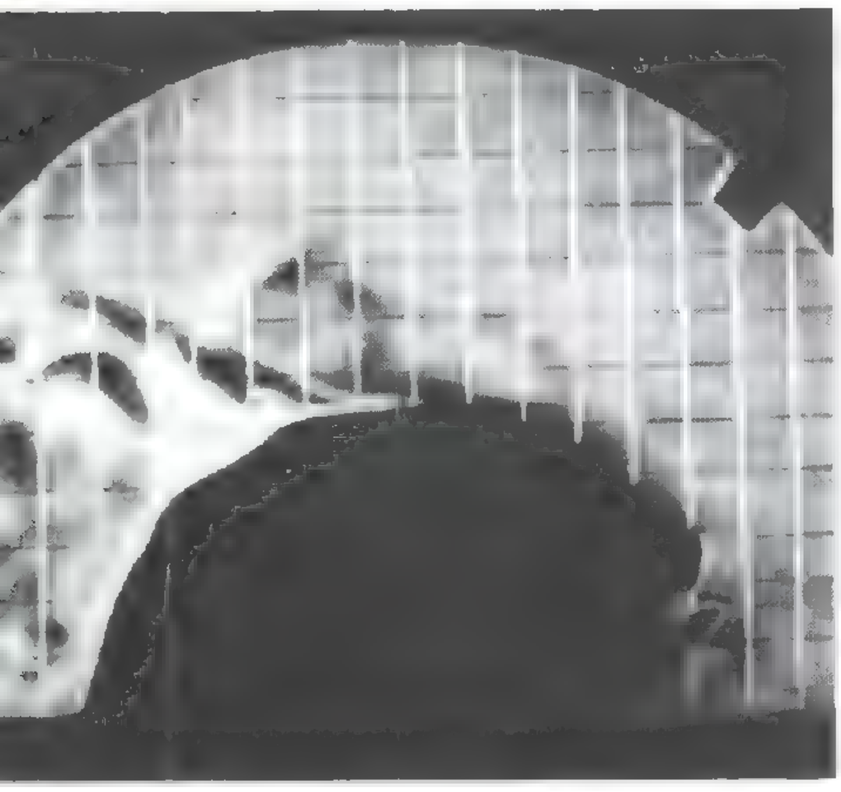
Figure 1. Diagram of the schlieren system. Light passing around the hot air from the turtle is focused on the razor blade and about half reaches the camera. Light passing through the left side of the air column is bent left and all of it enters the camera, appearing light (see Fig. 2A). Light passing through the right side is bent right and is blocked by the razor blade, appearing dark.

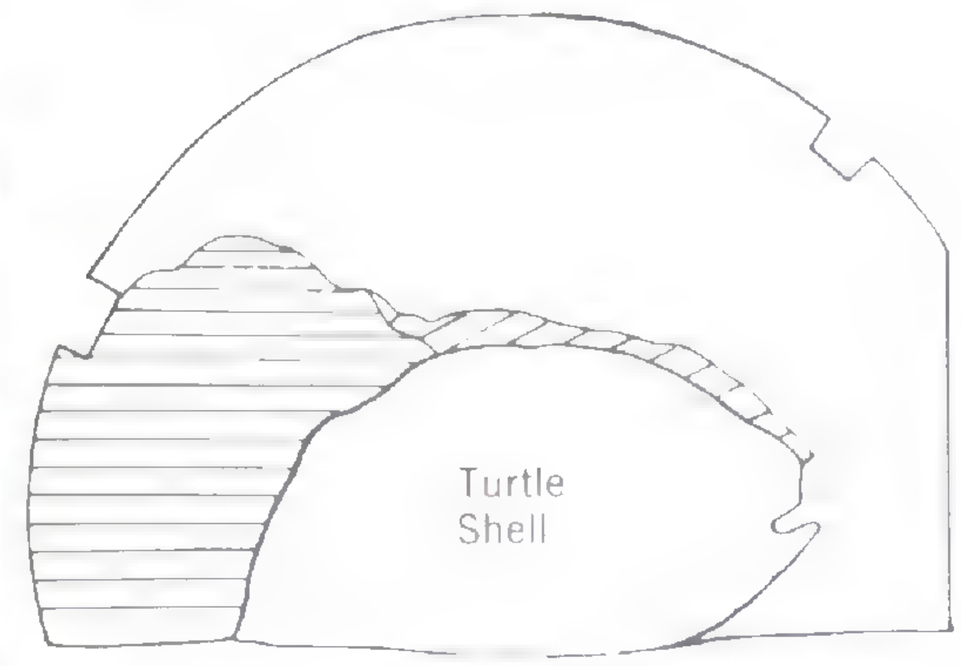
of the brightly lit slit on the very edge of a razor blade, and a camera is placed behind the blade focused on the mirror. A column of warm low density air rising from, say, a warm turtle in front of the mirror will cause the light to spread out or divirge as shown. As a result light from the left hand part of the column will not strike the razor blade, causing the mirror to appear lighter than the surrounding area. Similarly light from the right hand part of the column will be deflected to the right, striking the blade, and causing that part of the mirror to appear darker in the picture.

The photographs in figure 2 show such a case, except that we have used an empty shell rather than a live turtle since a clear picture requires that the shell be heated to a higher temperature than a live animal can tolerate. The empty shell formerly belonging to a three-toed box turtle (*Terrapene carolina triunguis*) has been heated to 110°F in air at 77°F. The top photograph was taken in perfectly still air and shows a column of hot air rising from the center of the shell, with a smaller column from the front. The adjacent

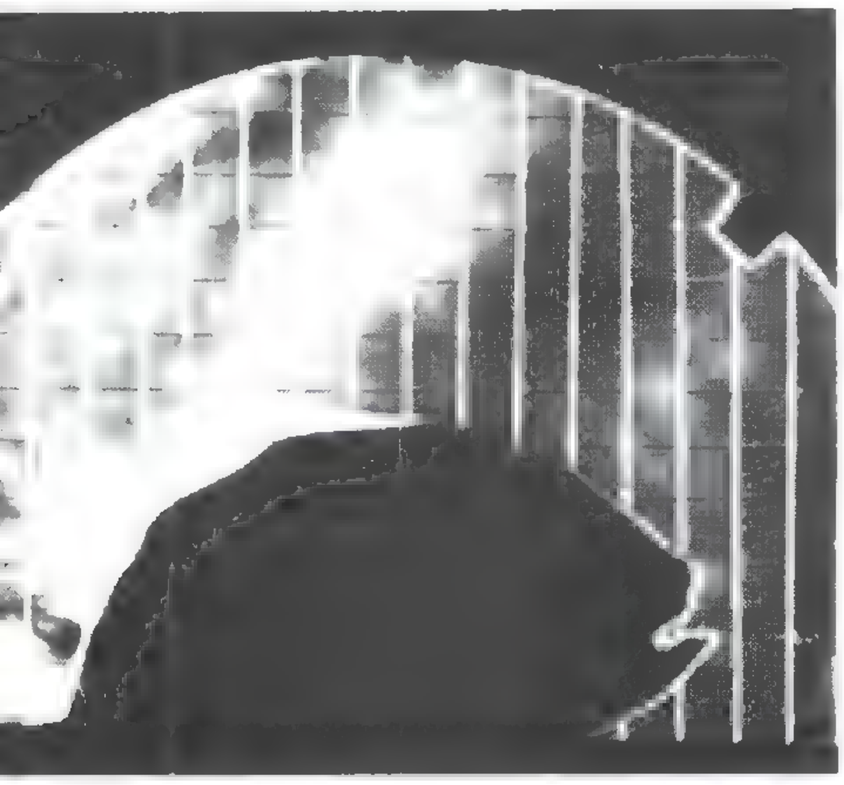


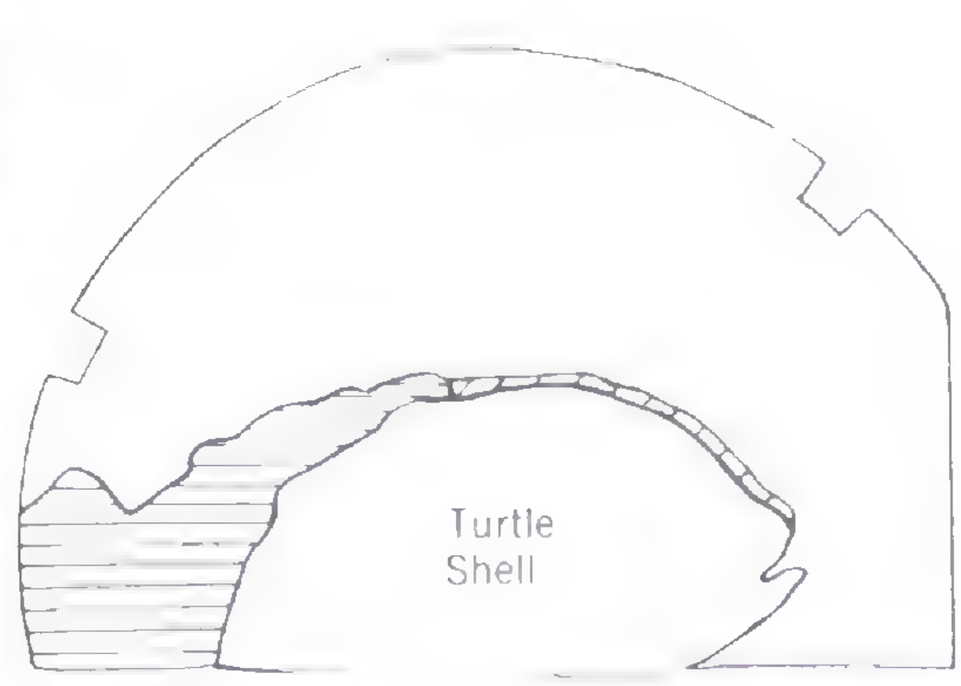
A. Still air.



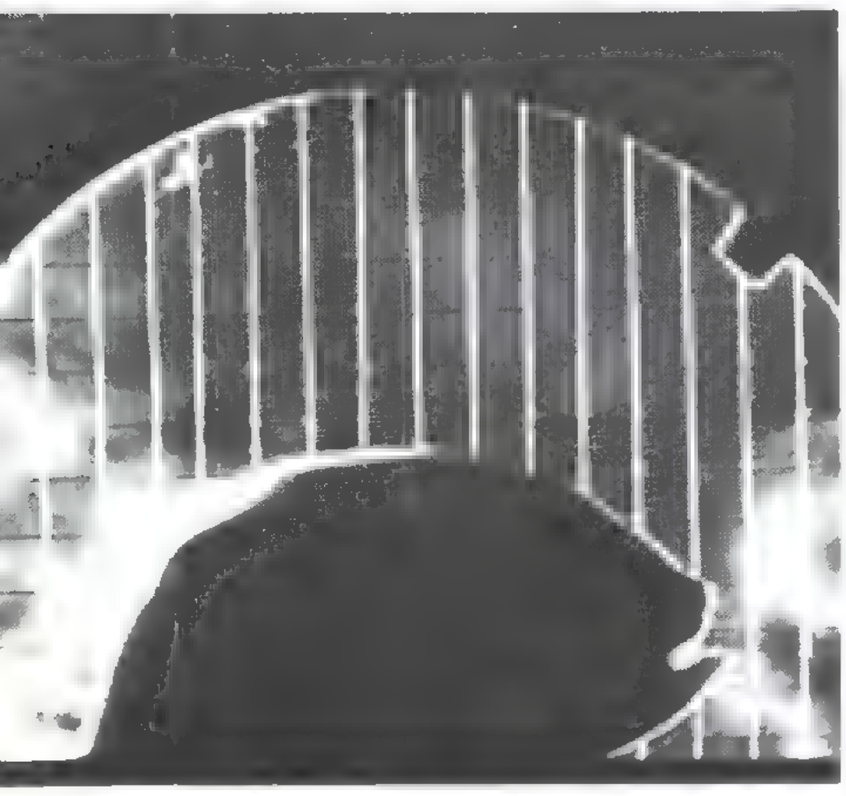


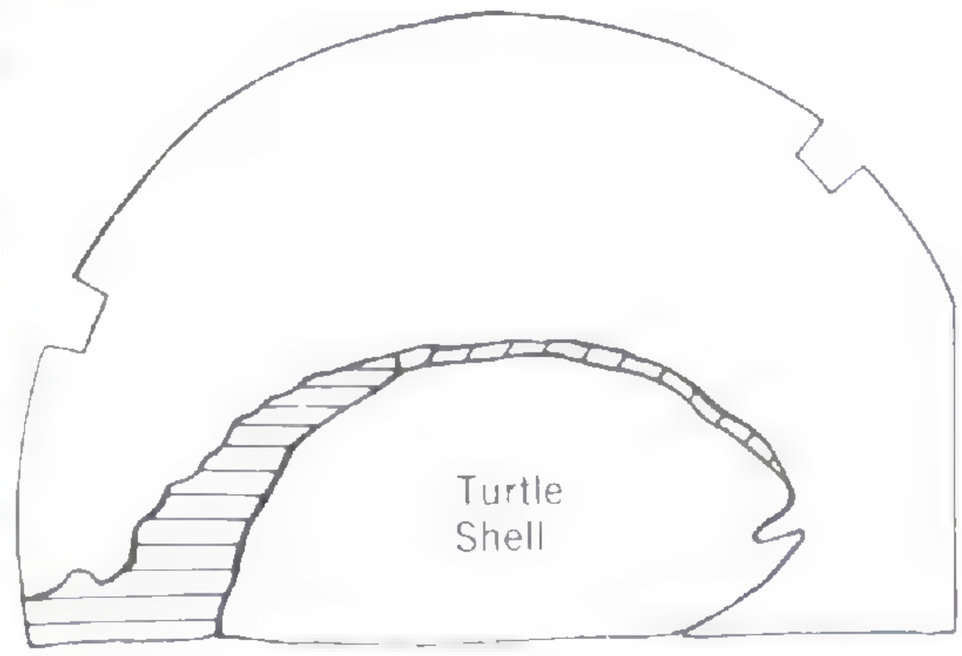
B. 1/2 mph wind.





C. 1 mph wind.





D. 4 mph wind.

ure 2. Schlieren pictures of a hot box turtle shell, with regions of laminar and
oulent flow shown in the accompanying diagrams.

diagram outlines the columns of warm air. This picture clearly shows the "blanket" or boundary layer of warm air which surrounds the warm turtle shell. Even a slight breeze of 0.5 mph, as shown in the second picture, blows away some of the blanket, cooling the turtle. Stronger breezes, of 1 and 4 mph shown in the last two pictures remove almost all of this blanket from the front of the shell, thinning it in back. The difference between 1 and 4 mph is very small both in the pictures and in the amount of cooling. The cooling effect between 0 and 1 mph is much larger than between 4 and 20 in fact, since little is changed after the boundary layer blanket is removed.

The pictures also show that the air flow over the turtle is reasonably smooth and orderly, as expected, so that only a few measurements will be required to determine the convective heat loss for the three toed box turtle. Similar experiments are being done on aquatic turtles such as the slider (*Pseudemys* sp.). We hope to compare the results to see if there is any thermal advantage in the high domed shells typical of land turtles.

Similar experiments are planned for birds and mammals of suitable size. These experiments will give us information about the flow over these shapes and check the validity of our current use of convection coefficients of cylinders for birds and mammals. If necessary we can then plan a suitable series of experiments to measure the convection coefficients for typical birds and mammal shapes.

Of course, the coefficient of convective heat transfer can be measured without using schlieren photography at all, although it is simpler if schlieren photographs are available. The most important use is in allowing the investigator or a student in the classroom to visualize the behavior of air flow over a plant or animal, giving a better intuitive feel for the functioning and importance of the convection term in the energy budget. □

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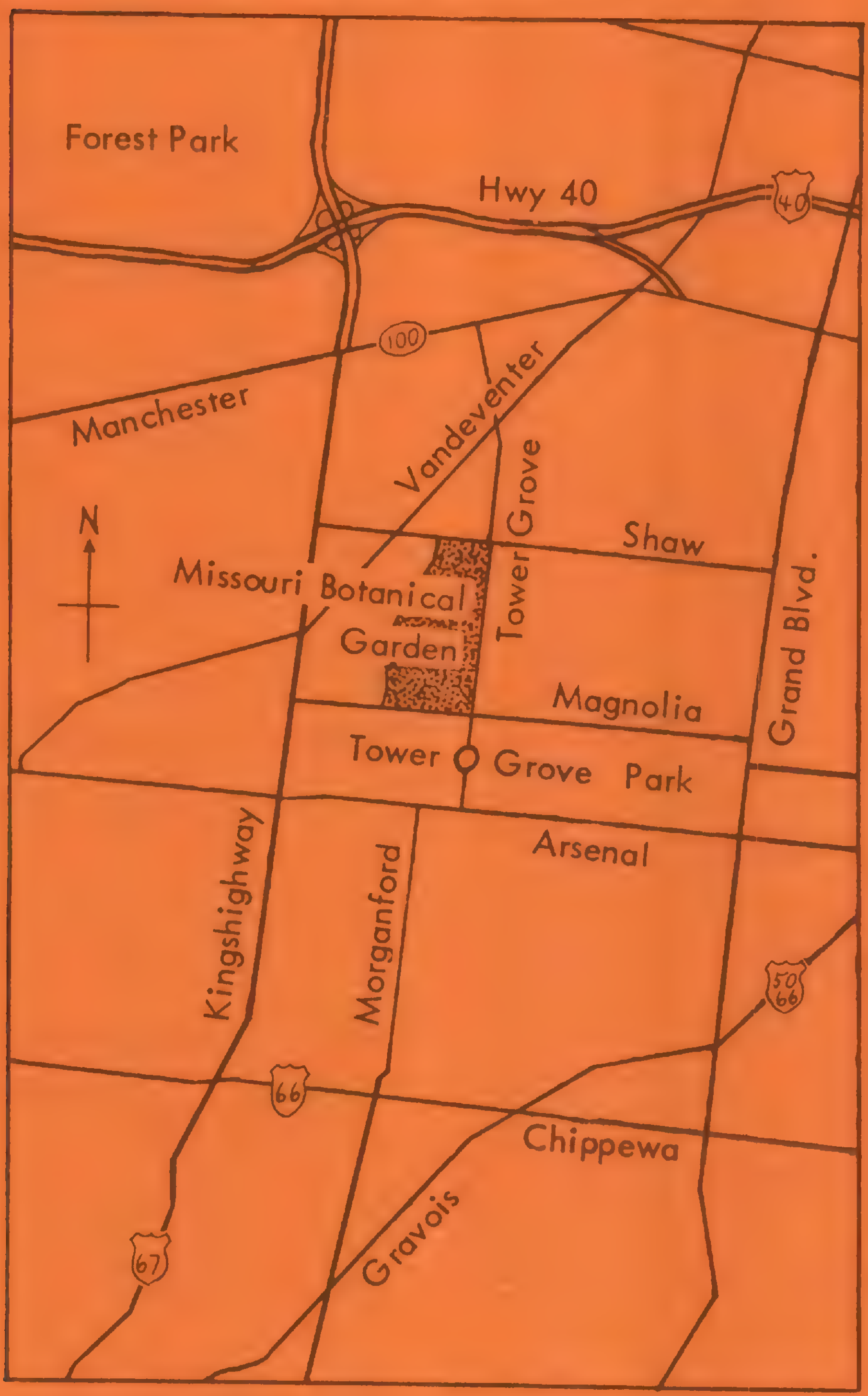

MISSOURI BOTANICAL GARDEN

BULLETIN

VOLUME LIX NUMBER 5

SEPTEMBER-OCTOBER 1971

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The Almond Tree

(cover)

Carla Lange

THE COVER ILLUSTRATION of this *Bulletin* is of the almond tree *(Amygdalus communis)*, a member of the family of the Rosaceae, taken from William Turner's *Herball* printed in London in 1551.

William Turner describes the "vertues" of the almond tree as follows: "The broth of the rootes of the bytter almon tre, if they be broken and soden, scoureth away the frekelles and spottes of the face. They take away y hede ake, if they be layd to the tempels, or soched wyth vynegre and rose oyle. And wyth wyne; they are good for wheles and litle sores: and wyth hony they hele rooting, and running sores, which runne from place to place: and the biting of dogges. The same eaten taketh ake away . . ."

The two principal varieties of the almond tree, the sweet and the bitter, are distinguished by their fruits, which are similar in size and appearance. The flowers of the almond trees, which appear in early spring, are pink and white. It is believed that the trees growing wild bear bitter almonds, but when cultivated bear sweet almonds and that the tree bearing sweet almonds turns to bearing bitter almonds when neglected and left to grow wild.

The almond tree is indigenous to the Near East and North Africa, but since time immemorial has been cultivated in all Mediterranean countries. In the United States, the sweet almond trees are cultivated chiefly on the Pacific Coast, with most of the crop being produced in California.

Sweet almonds are usually used for culinary purposes and since they have a rather high oil content, are of considerable nutritious value. Their medicinal value is also due to the oil they contain which is supposed to relieve coughs, coarseness, and nephritic pains.

Almonds, when eaten in great quantities, may cause sickness and vomiting; and it has long been known that they are poisonous to animals, such as wolves, foxes, dogs, cats and various birds. The almond tree is closely related to the peach and cherry trees, and since the bitter almonds, when distilled, have a taste similar to that of the cherry, they have been used to make counterfeit cherry brandy. □

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Welcome to Dr. Raven from Dr. Gates

I WISH TO TAKE this opportunity to introduce to you the new Director of the Missouri Botanical Garden, Dr. Peter H. Raven, who comes here from Stanford University. The Garden is exceedingly fortunate to have as Director for the years ahead a man of the scientific stature and leadership quality of Dr. Raven. Although a young man, Dr. Raven's accomplishments in the fields of evolutionary biology, taxonomy, and systematics are outstanding.

I now join the ranks of the five directors (including Henry Shaw) who preceded me as head of this 112 year old institution. Each was in his own way an outstanding scientist of world renown. Dr. William Trelease 1889-1912, Dr. George T. Moore 1912-1953, Dr. Edgar Anderson 1954-1957, and Dr. Frits Went 1958-1963. Founder Henry Shaw directed the Garden himself from its public opening in 1859 until his death in 1889.

We have managed to survive thus far as a purely private institution which receives no direct tax support of any kind. As a private institution we have more freedom of operation and fewer of the encumbrances inherent with public institutions. All of our effort and devotion at the Missouri Botanical Garden is for botany and horticulture. The people of St. Louis benefit enormously from our location here. The value of the Garden to the City of St. Louis is in the many millions of dollars over the years.

It is difficult for me to leave this beautiful, enjoyable, and scholarly institution just at a time when our new herbarium-library-education building is in the process of completion and when nearly everything is in good order. Nearly six and one-half years ago, before Mark Paddock and I actually arrived in St. Louis, we made a proposal to the National Science Foundation for a planning grant to support our efforts in design of a new building. We received a grant of $14,000 for that purpose. We applied for funds in 1966 to build the building, but by then all NSF money for construction was cut off.

Nevertheless, we persisted to make our needs known while in the meantime a public fund drive was launched in St. Louis to help raise capital and endowment funds. In 1970 the NSF made a grant of $600,000 to the Garden to assist with the cost of the building. In doing so they recognized the fact that our herbarium and library are irreplaceable national and international assets of inestimable value. This was the only grant of its kind made by NSF during the last few years. This splendid new building, to be known as the John S. Lehmann Building, will be completed by the spring of 1972. What an absolutely thrilling occasion that will be! The nation can count its blessings when these great collections are safely ensconced in their new home.

My tenure with the Missouri Botanical Garden has been a happy and extremely satisfying experience. My success here has been due to the magnificent cooperation of the very loyal and hard working staff. But there are two people in particular to whom I owe an enormous debt of gratitude. Mark Paddock moved with me here from the University of Colorado as my administrative assistant and was later promoted to Assistant Director for Admin-

istration. Many of you have gotten to know Mark during our six years here. You have learned to appreciate his fine intellectual capacity, his enormous dedication to the Garden and its needs, his willingness to work long hours, including weekends and evenings, and his absolute integrity. Mark, I could not have accomplished the task of Director without your selfless assistance.

When I arrived at the Garden in 1965 and in need of a personal secretary I looked about the institution. It was evident to all concerned that Mrs. Florence Guth, secretary to Dr. Edgar Anderson, was by all odds the right person for the job. He willingly relinquished her services and Florence joined Mark and me in our office. The task was a difficult one because the work load in the Director's office is many times greater than the size of staff we can afford. Yet, Florence tackled the job and worked countless hours beyond the normal work week. Nearly every evening and many weekends the office lights were burning while Florence strove to keep up with the work load. She was never paid overtime; she was never given a bonus; and yet she always greeted me, staff members, and visitors with the most cheery salutation. How very grateful I am to you, Florence.

For the future, I wish Dr. and Mrs. Raven every success with this marvelous, beautiful, and much needed botanical garden.

David M. Gates
Director
1 September 1965—1 August 1971

New Director of Missouri Botanical Garden

Barbara Perry Lawton

PETER H. RAVEN, recently appointed as Director of the Missouri Botanical Garden, arrived in St. Louis to assume his new position on August 1, 1971. Dr. Raven has come to the Garden from Stanford University in California where he was an Associate Professor in the Department of Biological Sciences from 1965 to 1971.

Although born in Shanghai, China in 1936 where his father was in the banking business, Peter Raven is a native Californian. His family moved to San Francisco the year after he was born and he spent most of his life in northern California. Dr. Raven's family on both sides has lived in California since before 1850. On his mother's side, the Breen family was in the Donner party in 1846-47.

Dr. Raven has had a love of and interest in natural history and outdoor life since early childhood. By the time he was ten he was a member of the student section of the California Academy of Sciences, becoming a member of the regular Academy in 1945. It was this early association with the student section of the Academy that helped Peter Raven choose his future career in the natural sciences.

He has been an active member of the Sierra Club since 1948, and for several years was naturalist for Sierra Club outings high in the Sierra Nevada. These groups usually stayed at camps above timberline at elevations of 10,000 feet or more. During these summers, Dr. Raven collected extensively, and, in all, has made about 25,000 collections of plants in the wild. Early and continuing contact

The appointment of Dr. Peter H. Raven as Professor of Biology at Washington University and Director of the Missouri Botanical Garden was announced May 13, 1971.

with the natural world led Peter Raven to his "keen and longstanding interest in conservation and related issues, as well as in the preservation of the environment."

Dr. Raven received his undergraduate degree in botany with highest honors from the University of California, Berkeley in 1957. He received his Ph.D. in plant sciences from the University of California, Los Angeles in 1960. His interest in the evening primrose family (Onagraceae) dates from student days. Raven's studies of these plants, including *Fuchsia*, willow-herb *(Epilobium)*, godetia *(Clarkia)*, and evening primrose *(Oenothera)*, have focused on genetics, cytology, hybridization, and interpretations of geographical and evolutionary patterns. He hopes to make a model for evolutionary considerations of a particular plant family from these studies. Thus far, his worldwide studies of the evening primrose family (Onagraceae) have resulted in some forty published papers plus National Science Foundation support since 1962.

While the Garden's new Director is first and foremost a systematic botanist, his scientific interests have not been limited to studies of plant classification. He has been part of a team of botanists and anthropologists at the University of California working on the language relationships of groups of natives in the highland Chiapas, the southernmost state in Mexico. Ethnobotany, the study of plants in relationship to man, has played a key role in this ten year project which aims to find out how these natives view the living world.

Dr. Raven has also been studying plant-insect relationships and has published a number of papers on his work in this area. Studies concerning the relationships between native bees and other insects and the plants they visit and pollinate have led to studies of pollination biology as an index of plant specialization at the community level. Dr. Raven feels that this type of study, with the California work as a base, would be interesting and appropriate for the St. Louis area.

Studies and collections made during travels not only to Central and South America, but also to Australia, New Zealand, Cambodia, Thailand, India, Iran, Egypt, and Europe have given Dr. Raven a keen interest in the historical questions that are raised by the distribution of plant groups in an area. Many answers to these questions

concerning derivation and patterns of evolution can be found in the specific distributions of plants and animals in a given region.

Dr. Raven has published more than one hundred scientific papers in such journals as *Science, Scientific American, American Naturalist, Evolution, American Journal of Botany,* and *Brittonia.* He has also published three books including *The Biology of Plants* (with Helena Curtis, 1970), *Native Shrubs of Southern California* (1966), and *Papers on Evolution* (with P.R. Ehrlich, R. W. Holm, 1969). He is active in the scientific community as Program Director of the Flora North America Project (American Institute of Biological Sciences), as an officer or member of several committees involved with plans and projects in systematic and evolutionary biology, as former Editor-in-Chief of *Brittonia* and now member of the council of the Brittonia Society (American Society of Plant Taxonomists), and as a member of various scientific societies. He recently became a member of the Governing Board of the American Institute of Biological Sciences, and will represent the American Society of Plant Taxonomists.

Peter Raven first visited the Missouri Botanical Garden in 1961 when he was returning to California from a postdoctoral period in London. He was studying plants at major herbaria along the way and so stopped in St. Louis where he visited the late Robert Woodson and our Herbarium. Dr. Raven remembers being very much impressed with the recently completed Climatron. In the years since then, our new Director has been in St. Louis many times and has attended many of the Garden's annual Systematic Symposiums. In his words, he is "enthusiastically looking forward to becoming a permanent resident of St. Louis." Dr. Raven is married to the former Tamra Engelhorn and has two daughters, Alice Catherine, eleven, and Elizabeth Marie, ten. □

Dawn Redwood and Bald Cypress Trees

The Garden's dawn redwood and bald cypress trees will take on a new importance with the completion of the Lehmann Building. A double row of dawn redwoods and a large pair of bald cypress, located on the east side of the new building, will rise above the building and be reflected in its glass walls.

Paul A. Kohl

SINCE 1948 there has been a continuous round of publicity about the discovery of a new conifer in China in 1945 after the genus was first described in 1941. In the May, 1948 *Missouri Botanical Garden Bulletin,* Dr. Henry N. Andrews, paleobotanist on the Garden's staff, in his account of "*Metasequoia* and the Living Fossils," stated "It is a special tribute to the paleobotanist Shigeru Miki that he should have recognized in his fossils the remains of a distinct genus of conifers before his fellow botanists found it actually growing on the hillsides of central China."

Many articles about the discovery of the dawn redwood tree, *Metasequoia glyptostroboides,* have appeared in botanical and scientific journals, horticultural magazines, and newspapers in the past twenty-two years. For those who wish to pursue the details of this discovery and the botanical relationship to the coastal redwoods and the big trees in the West, and our bald cypress, there is

appended at the end of this article a list of references. Our chief interest lies in the manner in which this tree has grown and adapted itself to this climate and how it compares with the bald cypress which has been growing in St. Louis for many years.

The dawn redwood trees now growing in the Garden originated from a packet of seed received on December 26, 1947 from Professor of Dendrology, Wan-Chun Cheng of the Arboretum of the National Central University of Nanking. The seeds were sown in January, 1948 with good germination, practically one hundred percent. The trees grew rapidly and in 1952 Dr. F. G. Meyer, the Garden's Dendrologist at that time, moved them from the nursery to their present

Author

The seeds for these dawn redwood trees were sown in January, 1948. The trees are shown here in 1970 at age twenty-two years.

Author

Cones and seeds of the *Metasequoia* are small, with the cones less than an inch in length. The dawn redwood seedlings shown on the right are three months old.

locations south of Henry Shaw's country home and near Alfred Avenue west of the parking area. The trees grew rapidly and now after eighteen years in their present locations average sixty feet in height and twenty feet in width at the base of the foliage. The trees have many branches studded along their trunks and gradually assume pyramidal shapes. The soft, needle-like leaves give a feathery appearance but are coarser than those of the bald cypress trees. The bark is reddish and sloughs off in strips as the trunks expand.

When the dawn redwood trees were twelve years old the first cones were discovered but they were few in number and had no viable seeds. In 1970 no cones could be found on any of the trees. We had colder weather in early January than in recent years which might account for the absence of cones or this could have been an alternate year when no cones are formed. So far no staminate flowers or catkins have been observed, a condition which might be due to climatic conditions or lack of age of the trees. In all other respects the trees have grown well and it would seem that seeds should be produced in the next few years. Having the dawn redwood under observation for almost a quarter of a century we do know it grows rapidly and becomes a big, pyramidal tree much broader at the base than a bald

Author

These bald cypress trees in the northwest part of the Garden are relics of Henry Shaw's Arboretum.

cypress. In studying a picture of one of the largest *metasequoias* in the lower Suisapa valley in China, in the Proceedings of the California Academy of Science, July, 1953, it appears that as the tree grows older, the shape changes from pyramidal to columnar with large, drooping branches.

Dawn redwood trees grow too large for the average size garden and would dwarf the home. This is not a shade tree and it is unsuitable as a street tree because of it's broad base. The dawn redwood has received the most publicity ever accorded a recent plant introduction.

When the Missouri Botanical Garden and Tower Grove Park were established over a hundred years ago many trees and shrubs were planted under the direction of Mr. Shaw and his superintendent, James Gurney. The bald cypress, *Taxodium distichum*, a tree native to the southern part of Missouri, was planted in several places in the Garden and park and to this day these trees stand, proof of their longevity. They have lived through good and bad years, extremes in temperatures, droughts, storms, tornadoes and smoke palls and although they have matured they live on with hardly a sign of deterioration. Only twice in my fifty-three year association with the Garden have I known of a bald cypress being struck by lightning. Because of the tall, pointed tops of the trees one would expect them to be frequent targets of lightning. The sequence pictures of the "struck" tree show how well it recovered and produced a new leader. Now, after twenty-nine years one would never suspect that the tip had been snapped off by lightning.*

Metasequoias and bald cypresses may be classed as accent and specimen trees suitable for park planting and large estates. They are also good subjects for screen planting to block out unsightly objects. Bald cypresses grow where other trees fail and in the twenty-two years the *metasequoias* have been with us they too do not appear to be troubled by city conditions. In recent years many bald cypress trees have been planted along Market Street between 12th Boulevard and Compton Avenue. We know these trees would prefer a better

*Unfortunately, this tree had to be removed in December, 1970 as it was in the area where the new herbarium-library-education building is being constructed. The loss of this tree is compensated by the preservation of the stately, double row of dawn redwood trees which border this new building on the east.

location than along Market street, the driest place for any tree to grow with only a four-foot square opening of soil for air and water. Some of these trees have grown well and others are just barely remaining alive; still others have been destroyed where buildings are being erected. The bald cypress trees along Market Street will make an interesting study in succeeding years. Will they continue to grow under adverse conditions, mainly from lack of water, or will they eventually have to be replaced? It is, indeed, a difficult situation in which to grow any tree. In the heart of town in Lucas Park, immediately north of the central Public Library, is a fine group of bald cypresses planted to screen unsightly buildings and there is also a fine specimen opposite Union Station. One of the best plantings of cypresses is in Francis Park where rows of these trees border the lily pools.

Author

The bald cypress trees in Francis Park are very effectively lined along the formal lily pool.

Author

This large handsome bald cypress was struck by lightning October 22, 1941. (upper left photo) By 1952 (lower left), it had already developed a strong new leader, and in the 1970 photo (above) its old injury cannot even be seen.

Balancing the qualities of *metasequoias* and taxodiums for general planting we can tip the scales a little in favor of our native bald cypress since they have been growing in St. Louis gardens for so many years. We know how well they grow and the shape they assume as mature trees. *Metasequoias* grow rapidly and since they have attained a height of sixty feet in twenty-two years one wonders what their ultimate height will be. Nurserymen grow bald cypresses from seed but since no *metasequoia* seed is available they must grow them from cuttings. Both trees are conifers but they differ from other cone-bearing trees in that they shed their foliage in the autumn. □

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How to Grow Boxwood in the Midwest

Mary A. Gamble

This is the second of two articles by Mrs. Gamble, chairman of the Boxwood Study Group of the St. Louis Herb Society. The group presently is testing many varieties of Buxus *for hardiness in our area. Those proved hardy will be included in the Edgar Anderson Boxwood Memorial Garden.*

BOXWOOD HAS BEEN growing successfully for many years in many St. Louis gardens; but there are even more local gardens denied the beauty of this historic plant because their owners share the frequently expressed opinion that "you can't grow boxwood here."

This simply isn't so. Boxwood can be grown with relative ease in the St. Louis and adjacent midwestern areas if the grower respects these conditions: chooses his *Buxus* from the hardier varieties, preferably those already tested here to avoid undue disappointment; chooses the proper location on his grounds; prepares the soil and sets the plants properly; gives the plants the minimum care needed to insure survival and growth.

St. Louis is in a climatic zone with the coldest average temperature at which *Buxus sempervirens* generally can be grown successfully. But interestingly, it is not cold which is boxwood's chief winter enemy; there are numerous instances of its having lived through temperatures of 20 below zero Fahrenheit. It is the winter sun, the extreme fluctuations of temperature experienced often in a matter of hours in our chancy climate, and the winter winds which blow straight across to us from the Great Plains that do the damage. It is therefore doubly important for St. Louisans to pick the right spots in their gardens and grounds for their boxwood plantings. Thus the choice of the right location is the first challenge to growing boxwood in the Midwest.

What is a right location? First, it must have good drainage. Every other requirement can be met, but if a *Buxus* has to stand with its roots in water it will die. So, pick a well-drained spot. If there's a question in the gardener's mind, he should check after a rain to see if water stands in the selected spot for any appreciable time; if so, pick another.

With few exceptions, boxwood's next requirement is partial shade. A good many *Buxus* will grow in full sun but they will not thrive. But neither do they like full shade. A boxwood plant will make a more vigorous growth if it has sunlight for at least a portion of the day. If possible, it should get dappled shade and the morning sun.

Next, avoid full, open exposure. Above all, avoid the unbroken force of the southwest wind which is hot and dry in summer, cold in winter, and bad for boxwood and many other plants at any time of year. A wall, a woods, a slope, a hedge, a building can serve as protection from prevailing winter winds; but make sure the protective wall or building does not reflect damaging heat or retain excessive moisture. And if the boxwood is to be placed as a foundation planting make sure it is well out from under the roof overhang where rain water could pour on it and snow or ice fall on it.

Boxwood, with its shallow, matted root system, will not do well too near such shallow-rooted, thirsty trees as soft maples; it can be planted near, or in the shade of oaks and other deep-rooted trees.

A boxwood growing in the shelter of a high-pruned oak seems to have found its habitat.

So, let the gardener survey his grounds, eyeing them realistically from the boxwood point of view. And remembering that, if exactly the right spot or condition can't be found, "something usually can be done," to quote one of the late Dr. Edgar Anderson's frequent sayings.

Author

This stately *Buxus* grows in the northwest corner of the Linnaean Garden. It tops the ten foot stone wall, illustrating why a space of five feet in diameter must be allowed for specimen plantings. This *Buxus sempervirens* is another representative of the late Dr. Edgar Anderson's Balkan strain.

Boxwood, in its natural ranges or in a completely hospitable climate, appears not to be fussy about soil or its pH. But here in the Midwest, proper soil preparation is vital to the healthy, vigorous growth which is the plant's best insurance against all natural problems. The story of *Agram* illustrates the point. This *Buxus sempervirens*, which Dr. Anderson considered the most beautiful and distinctive of his Balkan collection, was placed in the Garden's Arboretum at Gray Summit on a downward slope in a relatively open area, protected by woods on one side and the rise of the slope on the other. The first *Agram* (named for a town in Yugoslavia) died to the ground in a severe cold spell in 1950. The present *Agram*, a cutting from the first, was planted in almost the same spot. When Dr. Anderson read my account in the original draft of this paper he noted that the plant's loss occurred "in the absence of proper soil preparation due to lack of funds."

The pH range accepted by a strong, healthy *Buxus* planted in friable soil rich in humus is broad. One authority gives it as 5.5 to 7.4. Dr. Frederick G. Meyer and Mr. Edgar Denison in their 1957 *Missouri Botanical Garden Bulletin, Broad-Leaved Evergreens for the Central Midwest* (Vol. XLV, No. 1), recommend for *Buxus sempervirens* a slightly alkaline soil—pH range 7.0-8.0—with an occasional sprinkling of agricultural lime to maintain the alkalinity. For *Buxus microphylla* they suggest a soil with 50% organic content and a pH range of 6.0-8.0.

Mr. Louis G. Brenner, formerly of the Missouri Botanical Garden staff and now Superintendent of Parks in Webster Groves, Mo., who has had extensive and extended experience in planting boxwood gives us the following two-part directions for proper soil preparation for *Buxus:* first, for those home-owners who have reasonably good soil with good tilth; and second, for those who live in new bulldozed subdivisions where they must develop the soil from scratch.

After making sure the drainage is good, all the first group has to do is dig a hole the depth of the ball (if a boxwood plant is more than 15 in. high Mr. Brenner advises moving it with a ball) and somewhat wider than the plant so there will be room for new feeder roots to expand easily. The bottom of the ball should rest on exca-

vated soil (never on fertilizer) and the ground level of the ball should be even with the soil around it (lay a yardstick across ball and surrounding area to check). In moving a very large plant it is a safeguard to let the filled soil settle before planting to avoid sinking of the plant below ground level.

Take the soil removed from the hole and work into it generous proportions of compost or peat moss (brown or black), add sand, and use this to fill in around ball, being careful not to mound it. (Do not use any commercial fertilizer in this mixture.) Tamp this soil down lightly around ball until level with it; then add a 1 in. mulch of organic matter such as peat moss, straw, etc. Now water the planting area lavishly, letting the water flow gently from the hose so there is no washing. Be sure the area is soaked but no water is standing. In the case of a balled, nursery-grown plant, do not cut back at this time. However, in the case of a field-grown plant which has not been root-pruned it is advisable to cut back some top growth to compensate for damage done to the root system in transplanting.

The best time to move a mature, balled plant in our area is late March when the soil can be handled. Fall moves are ticklish here because our chancy climate makes it difficult then to give the plant enough but not too much water. Smaller, potted plants such as those the gardener has raised from cuttings should be set out in mid-April.

New subdivision home owners have a harder job. After checking drainage, dig a hole 18 to 20 in. deep and 2 to 3 times the width of ball. Back fill this hole with a good soil mixture made up of equal parts organic matter such as compost or peat, sand and garden soil (use that you dug out if it's not too heavy). Let it settle so there will be no danger of its sinking with the plant until the surface roots are below ground level and thus in danger of drowning. Set in the plant, fill in around ball, mulch and water as before.

Large types such as *Buxus sempervirens Ste. Genevieve* should be allowed a space 5 ft. in diameter for specimen plantings. If you are planning a hedge of *B. m. koreana* with a permanent height of 1 to 2 ft. in mind, place the plants 12 to 18 in. apart. For the first few winters protect these plants by placing evergreen boughs between them; after they meet, each plant protects its neighbors.

Boxwood, for all its elegance, is a low maintenance plant. Its care begins with a prohibition: do not cultivate. Its matted, shallow root system is injured easily by a tool: rather, keep the plant mulched with organic matter to a depth of about 1 in.; renew as needed, and make sure it is in good array for winter.

Do not feed boxwood the first year the plant is set out. Instead, feed it the second year and every few years thereafter, or whenever its appearance suggests the need. We offer three suggestions from three good gardeners. Mr. Brenner suggests cotton seed meal, bone meal and small amounts of chileated iron and ferrous sulphate. Mr. Charles Krehrer, professional gardener at Shaw's Garden, recommends a mixture of 1/3 bone meal and 2/3 cotton seed meal. Mr. Clarence Barbre, local nurseryman and member of the board of the National Arboretum, had this to say: "It might be well to remind Boxwood Study Group members to apply fertilizer 10-6-4 at the rate of 1 to 2 lbs. per 100 sq. ft. just after the first freeze or in early spring." And he added, "Boxwood will grow rapidly if well fertilized."

Fertilizer should not be applied during boxwood's two annual growth periods. These occur in April and early May and again in September and early October. Fertilizer is best applied in very early spring before the rush of new growth begins. Generally speaking, the growth of boxwood is relatively slow; it should be steady and encouraged only in spring, never in fall.

Watering of boxwood should be repeated through the season, washing off foliage as well as soaking the soil. Frequent, light waterings are not good; soaking is. In the fall, don't water enough to stimulate growth; but just before winter sets in and the ground freezes, soak thoroughly. This supplies the moisture lost by transpiration and which cannot be replaced when the ground is frozen. This late watering is the single greatest step in protecting the plant against winter-burn. For a plant's first winter it may also be a good idea to spray the foliage with an anti-dessicant such as foligard or wilt-proof, says Mr. Robert Dingwall, chief horticulturist at Shaw's Garden. Do not prune or clip your new boxwood in fall or winter as this stimulates leaf growth.

Give the newly transplanted plants protection from the sun during their first winter. Christmas tree boughs can be laid around

Claude Johnston

Mr. Robert Dingwall, Chief Horticulturist at the Garden, demonstrates pruning techniques for the Boxwood Study Group of the St. Louis Herb Society. This plant is one of three *Buxus sempervirens* (Balkan strain) transplanted in spring 1970 from the Arboretum to the formal herb garden maintained at the south side of Tower Grove House by the Herb Society.

and over them. Snow should be brushed from mature box if possible to lessen breakage or injury to branches or twigs.

The pruning of boxwood is both hygienic and artistic; it is as important to the health of the plant as to its appearance. In its simplest form, when the gardener is working to preserve or accentuate the natural shape of the plant, pruning is a minor garden art; when it takes the form of topiary in which the plant is forced to grow in unnatural shapes, it requires mechanical, artistic and gardening skills of major proportions, plus infinite patience.

"Boxwood should be pruned by eye as well as by hand," says Mr. Dingwall. Pruning, he points out, is selective; shearing is cutting flat, like giving a hair cut. Pruning is done to emphasize and maintain the shape of a plant, to change its shape when desired, to take out dead wood, to open up the plant to air and light, to control disease and sucker growth, to rejuvenate. With selective pruning, says Dingwall, a gardener over a period of three years can change the size and shape of a boxwood plant.

The shaping of a boxwood begins with soft-pinching the top and side branches of a young plant to encourage low bushing. The pruner's first objective is to force the plant to bunch at the bottom; after that has been accomplished its height can be allowed to develop. The plant should be flat on the bottom; even when you are shaping a ball or pruning a globular-shaped plant, the bottom should be left flat so sunlight reaches all layers. This is the same principle as pruning a hedge with a batter, the term which gardeners have borrowed from bricklayers to describe the slight inward slope towards center top. In bricklaying the batter gives stability; in hedge-shearing it permits light to flow down the outer slope of the plant from top to bottom.

With a larger or mature boxwood pruning begins with cutting out all dead wood from the center of the plant, then snipping selectively down the slope of the plant, being careful not to interfere with its natural shape. When necessary the branches can be tied loosely (old nylon stockings are ideal for this purpose) to keep them from flopping and for protection against wind and water damage.

"Boxwood pruning," says Mr. Krehrer, "is best done when the new spring growth is about 2 in. long and is hardening up, usually

in late April or early May. For specimen plants shorten for natural shape; prune on present or previous year's growth; and don't give the plant a crew cut!"

The height of a boxwood can be controlled by shortening branches in its upper regions. This also lets in light which helps develop a strong framework against damage from snow, water, wind. Just clipping a boxwood, as one does privet, tends to weaken the plant. Where the center growth of a boxwood is sparse it can be cut back to encourage new growth. A boxwood can be pruned severely and will recuperate as the plant has great regenerative powers. But when drastic pruning has been practiced, the plant should be fed. Normally, pruning is not drastic, nor does it need to be frequent. "About every two years should do the job," says Charles Krehrer.

Boxwood hedges, on the other hand, should be pruned every year to maintain desired height and width. Neglected too long, the hedge can never be brought back below a certain point because it would be necessary to cut too deep into hard wood. Clip hedges in early spring before new growth begins to flop, lean or tip. "If you wait until it tips," says Mr. Krehrer, who has been pruning boxwood hedges for many years, "you will have a slightly uneven effect because no shears can then catch every tip."

As you prune and sanitize your boxwood make sure no ground cover plants have become entangled with the box; keep them well away from the base of the plant. Each spring remove foreign matter such as dead leaves, etc., from interior of plants and police ground area lightly.

Boxwood bears its insignificant pale greenish flowers in early spring and fruits in autumn. If you want to try propagation from seed, gather the seeds the moment the capsules appear ready to open; otherwise you will share Dr. Anderson's Balkan experience of searching for them on hands and knees. Once gathered, sow seeds in a porous soil mixture. In about three years you should reap a harvest of 6 in. plants, no two alike.

By far the more usual method of boxwood propagation is asexual or vegetative, by cuttings through which we get offspring the spittin' image of the parent plant. Box cuttings root readily and when made at an advantageous time, rather quickly. Floriculturist

Buxus illustration from William Turner's *Herball* (London, 1551).

Paul A. Kohl says they are best made in late June or early July when the plants are over their first rush of spring growth and the wood is beginning to harden. Made earlier, the wood is too soft and sappy; later, it is too hard. Mr. Martin R. Bagby, for many years propagator at the Missouri Botanical Garden Arboretum, says he has best results from cuttings made in August. However, if active growth periods are avoided and semi-hard wood selected, cuttings can be made successfully virtually the year 'round.

Make cuttings of dwarf types about 6 in. long, of shrub and tree types about 8 in. Here's a hint from Mr. Kohl: make them of a branched rather than a single sprig. This gives a head start on a nice, bushy little plant. After making cuttings, strip 1/2 to 1/3 of bottom leaves, dip cut end into hormoden 3 or root-tone 10 and insert into

moist rooting medium. Keep moist and wait until a strong root structure has developed; then pot, using a regular potting soil and 2-1/2 to 4 in. pot.

The rooting medium may be straight sand, straight perlite, a half-and-half mixture of sand with perlite, vermiculite, or peat moss; or it may be a composty spot in a shaded, sheltered area, or the north side of a wall where sunlight never strikes. For this latter Mr. Bagby describes what he calls an easy outdoor method for fall cuttings. Dig out a strip to a depth of 8 to 10 in. (or sink perforated box into ground to that depth); put layer of gravel in bottom of hole or box, fill with mixture of equal parts brown peat and sand; tamp and soak; insert cuttings; soak again; protect with a few leaves and forget until spring. Many gardeners report good results with outdoor rooting. Certainly it is more carefree than setting up a home-made lippigator indoors: Needless to say, the best plants result from cuttings from healthy, vigorous, attractive parent stock; like mother, like daughter. If possible, young boxwood plants should spend their first winter indoors. They can be set out in their second spring, either in a nursery bed or where they are to grow.

One authority notes that most boxwood troubles are man made. A healthy boxwood, properly planted in the right setting, almost takes care of itself. Boxwood's chief natural problem in the St. Louis area is the winter-kill which occurs in the bright warm sunshine of late winter and early spring. Proper placing, planting, and care will keep loss to a minimum.

This writer came late to an appreciation of boxwood. When I said as much to Clarence Barbre he replied, "Waste no time on vain regrets," and handed me a beautiful little *Buxus*, one of Dr. Anderson's notable Balkan strain. When my husband and I took up gardening as a joyous and challenging avocation some 25 years ago, we listened when other gardeners said, "Boxwood is beautiful, but you can't grow it here." But we kept seeing it and finally realized that you can grow it here, if you have the right spot and will take care.

Care is the key. Care in choosing the variety, care in picking the site, care in planting, care in maintenance. There are endless right spots in thousands of handsome St. Louis gardens; and there

are many varieties of *Buxus sempervirens* and *Buxus microphylla* that will thrive and lend their beauty, grace and timeless distinction to those gardens whose owners will take the modicum of time to give proper care.

Boxwood belongs historically and esthetically in every beautiful garden where "man's oldest garden ornamental" can be grown. Today there is yet another reason for its presence; in our increasingly rootless society it is somehow reassuring to have this evergreen symbol of eternity growing in one's garden. □

The Music of a Scientific Name

Some scientific names are beautiful just in themselves. Take the name of the side-oats grama, the little western grass which grows at the edge of the cliff in the Arboretum at Gray Summit (as it does on so many Western mesas). It was named Boutelous in honor of Claudio Boutelou, a Spaniard who wrote about floriculture. Said several times in quick succession and with a rising inflection, "Bouteloua-Bouteloua-Bouteloua!" it sounds almost as musical as water coming out of a bottle. E.A.

Reader Survey

WE WOULD LIKE to find out what type of article and subject matter most interests you, the reader of the *Bulletin*. Answer the following five questions and help us make the Missouri Botanical Garden *Bulletin* a better magazine.

1. I would like to read articles on the following subjects in the *Bulletin*. (Please circle any of the following, and/or add your own ideas.)
   a. Home gardening
   b. Gardening advice column
   c. Landscaping
   d. Horticulture at the Garden
   e. Ecology and environment
   f. Research based at the Garden
      1) Panama station
      2) Scientific expeditions
      3) Unusual plants collected
      4) Advances made in cytology, genetics, etc.
   g. Natural history of St. Louis area
   h. Features about interesting plants
   i. Botany, including technical information
   j. Herbarium, plant collections
   k. Library, rare and notable books
   l. People at the Garden

2. I read every *Bulletin:* Cover to cover. Always. Frequently. Sometimes. Never. (Please circle one.)

3. (Please complete the following.) I always read the articles about . . .

4. (Please circle one or more.) I have a scientific background. Gardening interests. Interests in natural history. Other interests. (please explain).

5. Please use the following space for any other comments or suggestions.

Thank you for your help. Please cut this page out of your *Bulletin,* and send the completed questionnaire to:

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Visit Your Missouri Botanical (Shaw's) Garden

The Missouri Botanical Garden's main entrance is at Tower Grove and Flora Place. The Garden is served by both the Sarah (No. 42) and the Southampton (No. 80) city bus lines.

The Missouri Botanical Garden Arboretum— 2100 acres— established at Gray Summit, Missouri, in 1926, is open to the public.

The Garden—70 acres—is open every day except Christmas and New Year's. For the main entrance, grounds, Climatron, display greenhouses, and Floral Display House:

May 1 through October 31 . . . . 9:00 a.m. to 6:00 p.m.
November 1 through April 30 9:00 a.m. to 5:00 p.m.
Sundays and Holidays . . . . . 9:00 a.m. to 7:00 p.m.

For Tower Grove House:

May 1 through October 31 . . . . 9:00 a.m. to 5:00 p.m.
November 1 through April 30 10:00 a.m. to 4:00 p.m.

The Display House presents four major shows: November, Chrysanthemums; December, Poinsettias; February, Orchids; April, Spring Flower Show. During the year other shows, competitions, and festivals are sponsored by various garden clubs and flower societies.

Courses in botany and horticulture for adults are conducted by the Garden staff. Children's nature classes are provided free on Saturdays from mid-September to early June. The Pitzman Nature Program is held for children during the summer. The Garden is world famous for its scientific research program. The scientists of the Garden hold teaching appointments on the staff of Washington University.

The Missouri Botanical Garden was established for the public's benefit in 1859 by Henry Shaw. The Garden, a non-profit institution, relies for support solely upon contributions from the public, the Arts and Education Council, and income from the Shaw estate. The Garden receives no city or state tax support.

Support your Garden and take part in Garden activities through the Friends of the Garden. Information may be obtained from the Main Gate or by mail or phone (865-0440).

MISSOURI BOTANICAL GARDEN

BULLETIN

VOLUME LIX NUMBER 6

NOVEMBER-DECEMBER 1971

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The Missouri Botanical Garden is a Fund Member of the Arts and Education Council of Greater St. Louis.

Cypress Tree
(cover)

Carla Lange

THE COVER IS the cypress tree *(Cupressus sempervirens)*, family of the Cupressaceae and the order of the Coniferales, taken from a woodcut of William Turner's 1551 *Herball*. The name of this genus came from the old Latin word *cupressus*, derived from the Greek word *kuparrisos*.

It is an evergreen tree with flattened, scale-like leaves which grows up to eighty feet. Originally a native of the southern part of Italy, the Levant, (the countries bordering on the eastern Mediterranean), the southern part of Russia, and China, it has been cultivated as an ornamental plant in all the warmer parts of Europe. In the United States it is hardy only in the southern states and California.

According to Pliny, there were cypress trees growing in the Rome of his time (the first century A.D.) that were older than the city itself. The gates of St. Peter's church at Rome were supposedly made out of the wood of the cypress tree and not only lasted for many centuries but remained in mint condition until they were replaced by brass.

Because of the dark, gloomy color of its leaves, especially in winter, the cypress tree was held in high regard by the ancients as a suitable ornamental plant for their burial places and was used at the funerals of persons of distinction. Since the cypress tree grows no more when once cut down, it was regarded as a symbol of the

dead and perhaps for that reason was sacred to Pluto. Even in modern times, it is often referred to in Italy as the tree of night.

According to William Turner, it was introduced into England in the sixteenth century. The famous English botanists, Philip Miller, born in 1691, author of the well-known *Gardener's Dictionary*, which was published in numerous editions, and John Evelyn, born in 1620, strongly recommended a more general cultivation of the cypress tree in England because of its valuable timber, since the wood is close-grained and very durable in soil and even in water.

The plant may be raised either from seed or from cuttings of the young shoots; the seeds obtained from the cones should be exposed to a moderate degree of heat and should be sown at the end of March or beginning of April in a rather light and fine soil and be covered with half an inch of soil. The plants should be well protected in winter to withstand the cold and frost.

Cypress trees growing in thickets and giving off an aromatic scent are supposed to restore the health of those suffering from aches in the chest. Because of the tannic acid contained in the fruits of the cypress tree, an astringent is derived which was used, according to Dioscorides, with excellent results to tighten the blood vessels in cases of nervous disturbances. Its effect is similar to that of another botanical astringent, witch hazel. The fruits of the cypress tree boiled in water cause a vapor which is supposed to efficiently cure whooping cough and other coughs resulting from the grippe. Dioscorides also says that the seeds of the cypress tree may be burned as an incense to keep away the mosquitos and other flying insects. □

MISSOURI BOTANICAL GARDEN BULLETIN

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Cover design by Peter Geist.
Photocopy by Todd Studios.

Howard L. Hibbs Appointed Assistant to Director Raven

HOWARD L. HIBBS, formerly Assistant Treasurer—Corporate Taxes at Falstaff Brewing Corporation, was appointed assistant to Director Peter H. Raven on June 16, 1971. Mr. Hibbs succeeds Mark Paddock, administrative assistant to the past director, Dr. David M. Gates. Dr. Gates and Mr. Paddock have moved to the University of Michigan where Dr. Gates is Professor of Botany and Director of the University of Michigan Biological Station.

Mr. Hibbs, who took early retirement from Falstaff, graduated from Washington University in 1930 and obtained a Masters Degree in Economics from Washington University in 1931. He held positions with several St. Louis corporations, in general and plant accounting and auditing as well as personnel evaluation and administration, before joining Falstaff in 1949 as a tax accountant.

Mr. Hibbs is a former president and chairman of the board of the St. Louis Chapter of the Tax Executives Institute, Inc., and a former national vice-president and director of the Institute. He is the founder and former national chairman of the Taxation Committee of the United States Brewers Association, Inc., has served as an industry member of the International Association of Assessing Officers, and of advisory groups to the Internal Revenue Service in their St. Louis district and their Chicago region. He is also a member of the National Tax Association and is on the Taxation Committee of the California Manufacturing Association.

Mr. Hibbs and his wife, Elizabeth Marie, live in Warson Woods, Missouri. They have two grown children, a daughter, Mary Ruth Cadwallader, and a son, Thomas. □

Construction of John S. Lehmann Building Progresses Well

Peter H. Raven

THE MISSOURI BOTANICAL GARDEN is currently in a period of rapid growth and activity, and one of the most obvious signs of this has been the rapid progress on the John S. Lehmann Building. Ground was broken on December 7, 1970, and visitors since have been able to watch the structure take shape. The Herbarium and Library will be housed in the new building, situated west of the Administration Building, and there will be space for those working with these important collections. Handsome new quarters will likewise be provided for the education department, including a modern, 300-seat auditorium.

This imaginative new building will be one of the finest in a botanical garden anywhere. It was designed by Hellmuth, Obata and Kassabaum, who also were the architects of the recently completed Equitable Building at #10 Broadway in downtown St. Louis. The same type of one-way glass, which cuts out 85% of the incident

Terry Luikart

View of the new John S. Lehmann Building as it appeared on Sept. 22, 1971. This photograph, taken from the third floor of the Administration Building, looks west.

rays even in full sunlight, is used in both structures. The structure is now completely enclosed in its glass walls, which will reflect views of the Garden outwardly. Those working within will be able to look out through the one-way glass, thus emphasizing the close connection between the research and other activities within the building and the Garden itself.

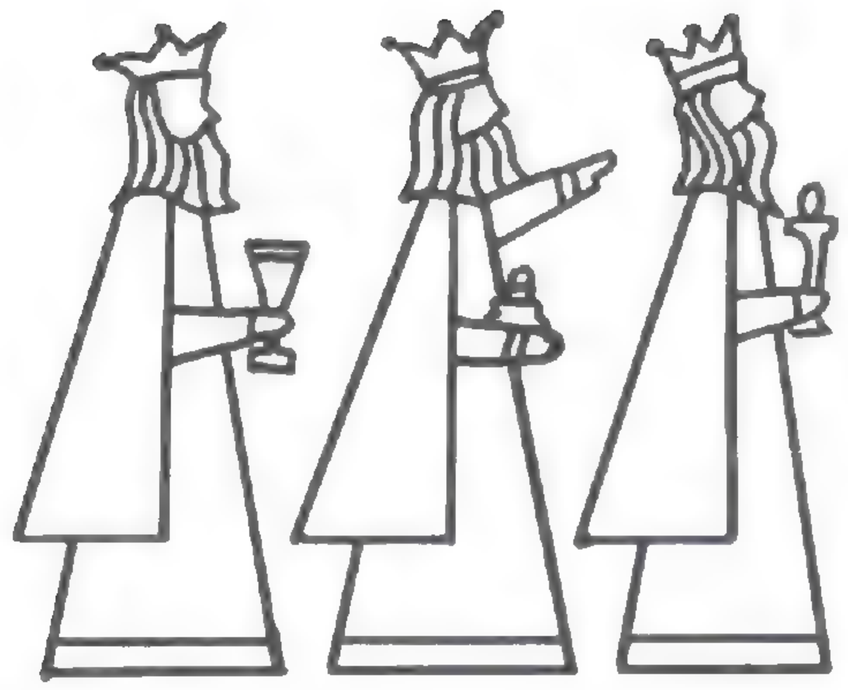
It is interesting to note that Henry Shaw foresaw the need for this new building at least as early as 1885, when he empowered the Trustees to erect a second museum and library building if the need developed. The cost of the Lehmann building, a two-level, 50,000 square foot structure, is approximately $1.8 million, of which $600,000 was obtained in a grant from the National Science Foundation and the balance as a result of the Garden's recent successful Capital Fund Drive. Endowment funds raised in the drive will be used to support the operation of the building.

It is most appropriate that the new building bear the name of John S. Lehmann, who was a member of the Board of Trustees of the Garden from 1940 to his death in 1967. Mr. Lehmann served as President of the Board from 1953 to 1958, and for a brief period as Acting Director of the Garden. He devoted much of his time and attention to the Garden, and also contributed very generously to support its activities financially.

Mr. Lehmann was very interested in furthering botanical and horticultural knowledge, and the new building bearing his name will represent a significant expansion of the educational and research facilities at the Garden.

Other projects currently underway at the Garden or soon to be initiated include the partial renovation of the Administration Building, erection of new experimental greenhouses, and the enlargement of the Garden Gate Shop. For all of these projects, and for its ability to sustain itself as an attractive and important feature of the community, the Garden is dependent upon the continuing generosity of its friends, both directly and through the annual fund drive of the Arts and Education Council.

The work on the building is proceeding on schedule, and it is hoped that it will be completed in early March. The move should be finished by April, with dedication ceremonies tentatively scheduled for early May. □



Copál, Frankincense, and Myrrh

Duncan M. Porter

WHEN AN ENGLISH-SPEAKING PERSON hears the word incense, he is most likely to think of frankincense and myrrh, two words inevitably linked with Christmas. These two fabled plant products are derived from the aromatic gummy resins of two Old World genera of the torchwood family (Burseraceae). Resins are found in the bark and wood of family members, causing them to burn easily and brightly—hence the common name.

Frankincense is obtained from several North African, Arabian, and Indian species of the genus *Boswellia*, named in memory of Dr. John Boswell, an 18th century Edinburgh physician. Myrrh comes from one or two species of *Commiphora*, a Latinization meaning gum-bearing, from the same area. These are all shrubs or small trees of arid or semiarid habitats. They are sought out in the wild by resin collectors, who obtain their products by slashing the trunks and collecting and drying the resinous gums as they ooze from the cuts. It has been said that even before the time of Christ some Arabians were becoming as rich exporting incense as they are today from exporting oil. Frankincense and myrrh still have their religious uses in incense, but today most of us are more familiar with them as sweet-smelling constituents of perfumes, mouthwashes, dentifrices, and face powders.

A Latin American, on the other hand, thinks of incense in terms of copal. Copál also is obtained from members of the torchwood family, in much the same way as are frankincense and myrrh. However, it comes from indigenous species of torchwoods *(Bursera)*, candlewoods *(Dacryodes)*, incense trees *(Protium)*, gommiers *(Tetragastris)*, and bastard cedars *(Trattinnickia)*. This Aztec word today

Author photo
A fence of gumbo-limbo trees along the Pan-American Highway in the province of Veraguas, Panama. These trees have grown from branches placed in the ground.

is applied in commerce to aromatic gums of various origins. However, true copal comes only from these New World trees.

Certainly the most common and widespread American member of the family is gumbo-limbo *(Bursera simaruba)*, which occurs throughout the Caribbean region from northeastern Mexico and southern Florida to northern South America. This species has many vernacular names, the most common being gumbo-limbo for the English-speaking and *indio desnudo* for the Spanish. The latter means "naked Indian," and refers to the coppery-red bark of the tree's trunk, which has a more than fanciful resemblance to aboriginal skin.

Gumbo-limbo has many uses, the most important probably being as a fence-post tree. Branches are placed in the ground and strung together by barbed wire. Soon, they take root and produce leaves. A common sight in lowland tropical America is the long lines of gumbo-limbo trees paralleling the roads—each the result of a lifeless-looking branch casually planted in the ground.

According to Standley and Steyermark in the *Flora of Guatamala*, copál is collected from gumbo-limbo in the following manner: "The trunk is notched and the resinous sap drains into gourds placed beneath. This is then boiled with water, the resin rising to the surface, where it is skimmed off and placed in cold water to harden. It is shaped into oblong blocks, very hard and brittle, which are wrapped in corn husks, tied at the ends with strips of corn husk,

and in this form taken to market, to be used as incense in the churches." Copál has been collected and used in this way since long before the European conquest of the New World.

Other species of torchwood also serve as sources of copál, especially in Mexico. This fragrant resin is important as well in domestic medicine, in making varnish, as glue, and as a cement for mending glassware or crockery.

Several species of the South and Central American and West Indian candlewoods also serve the same purposes. The most important of these appears to be the West Indian tabonuco *(Dacryodes excelsa)*, used as a source of incense for religious ceremonies in Puerto Rico.

By far the largest New World genus of the family is that of the incense trees, which has over 100 species. A number of these have been reported to be used for their copál, the most important being a a tree with the common name of copál (the aptly-named *Protium copál)*. It occurs in southern Mexico and Guatamala and perhaps also further south in Central America.

This tree is probably the most important source of copál in Guatemala, where it is harvested in a similar manner as that of gumbo-limbo. Its use is described by Standley and Steyermark: "At such places as Chichicastenango and San Francisco El Alto one constantly sees parties of Indians carrying censers in which copál is burned, emitting smoke and a fragrant aroma. They swing these censers for hours on the steps of the churches and in the interiors, as they offer up their prayers. These devout Indians, oblivious to their surroundings, are one of the most impressive sights to be observed in Guatemala."

Gommiers and bastard cedars are two small genera of mainly large forest trees. Most of their species are South American, but a few are found in Central America and the West Indies. In the West Indies copál is reported to be obtained from incienso *(Tetragastris balsamifera)*, as it is from caraña *(Trattinnickia aspera)* in Panama. In both cases it is presumably used in domestic medicine and incense.

Frankincense, myrrh, and copál are all similar products of the torchwood family. The next time that you read or hear of the first two, give a thought to copál, their aboriginal American counterpart.

The Mystical Cactus

John D. Dwyer

AFTER SEEING SO MANY movies and westerns on TV, it's easy to imagine a group of Indians, a century ago, squatting in a circle within a tepee. It is an autumn evening, and for the sake of romanticizing, let's say an Indian Summer evening. In our mind's eye we catch the flicker of the campfire within the smoky tepee, its flames dancing on the sloping sides and playing mischievously over the faces of the braves. The leader of the ghostly ring suddenly chants a prayer. As the last words fade from his lips he holds aloft in his cupped hands a pile of button-like objects. These, measuring about an inch in diameter, fascinate the diamond-like eyes of the spectators. What we are witnessing is a religious ritual, something akin to the Christian communion, and the sacramental is the sacred cactus, the peyote or mescal button (not to be confused with the peyote mushroom of the Mexican Indians, which has similar hallucinogenic effects).

Such a scene as the above was described by James Mooney who in 1891 as a member of the Bureau of American Ethnology, researched the Kiowas of the American West. The Kiowa Indian Agency in Oklahoma included the "Apaches, Comanches, Delawares, Kiowa, Wichita, and affiliated bands . . . who are descendants of one of the tribes known to the Aztecs (of Mexico) by the name of the "Chichimecas." The peyote ritual began in America long before the white man arrived, as is evidenced by the fact that the mushroom was depicted on stone in Pre-Colombian ruins in Mexico.

The adoration scene described above is but a segment of a long ceremony. The leader of the circle portions out four mescal buttons to each of his companions and each recipient plucks "out the small tuft of down from the center . . . the dry mescal is first chewed—then rolled into a large pellet between the hands and swallowed, the man rubbing his breast and the back of his neck at the same time to aid the descent. Accompanied by drum-beats and rattles the

braves sing throughout the night, pausing only at the height of the moon to drink the sacred water which is, like the peyote, an incarnation of power. A few hours after sunrise they indulge in a ceremonial banquet marking the end of the ritual."

The buttons are slices of the dried tops of a small cactus, *Lophophora williamsii*, measuring only a few inches in height, and at maturity producing a bell-shaped blossom which ranges in color from pink to yellow to white. The spineless cactus is rotund and ribbed; the ribs have a characteristic appearance, as if one were to form them on a ball of soft clay by placing the palm of the hand atop the ball and drawing the fingers stiffly upwards. It has a taproot like a carrot or dandelion. Like all members of the cactus family but one, *Lophophora williamsii* is native only to the New World, growing in the southern part of Texas near the Rio Grande and Pecos Rivers.

The first written description of the peyote cactus goes back to the 16th century when Padre Bernadino Sahagún who accompanied the conquistadores, observed the effects of the drug on some Mexican Indians. After eating the buttons, he tells us, they ". . . began to Indian denomination, the North American Church, who may use it dance; others wept . . . (some) seated themselves in their rooms and remained there as though meditating. Some had visions that they were dying and shed tears; others imagined that some wild beast was devouring them . . . after the intoxication of the cactus had passed

The sacred cactus of the New World, peyote was known in America and used in religious ceremonies long before the white man arrived.

off, they conversed with one another about the visions they had seen."

The hallucinogenic effects attest to the power of the drug mescaline, possessed by the cactus buttons. In 1938 the United States Food and Drug Administration ruled that the digging, sale, and use of peyote is illegal, except by members of a small, fundamentally Indian denomination, the North American Church, who may use as a sacramental. The peyote has never been declared a narcotic by the Federal Narcotics Bureau although the Bureau has intensified its interest as it contains the notorious substance LSD, which interestingly enough, is found in members of other unrelated plant families.

Noteworthy in Padre Sahagún's description is the phrase "as though meditating"; this is a mood that Friar Sahagún, by virtue of his calling, would be certain to recognize. This "meditation" effect caused virtually all missionaries bent on Christianizing the Indians, north and south of the border, to vigorously oppose the peyote ritual. Presumably they were unsuccessful to some extent, as Del Weniger points out (*Cacti of the South West*, U. of Texas Press, p. 95-96, 1970): "Many Mexicans came to relish a little of it now and then, just for the relaxation and sense of well-being it brings and in Central America most good markets will include among the herbs a stock of mescal buttons." One common name which is certainly suggestive is "dry whiskey." The peyote cactus is considered by some people to be very bitter and unpalatable.

Much has been written on the peyote cactus, and research suggests that the alkaloids in the peyote cactus, notorious for their hallucinogenic effects, may someday be turned to good use in the hands of the trained physician and psychiatrist. On the other hand, the vast living colonies of *Lophophora williamsii* which thrived on the banks of the Rio Grande and Pecos Rivers have been swept from the landscape, uprooted for profit or pleasure or adoration, while arguments were being waged in Washington concerning the legality of the plant. Ecologically the peyote cactus has met a tragic fate, a fate that could have been altered by more wise conservation practices. The legal restrictions placed on the drug are no doubt justified but it is sad that the mystical cactus has been caught between a wall of legality and a vista of scientific potential. □

Nepenthes Blooms Again

Leroy Fisher

SOME UNUSUAL PLANTS, once well known in the Missouri Botanical Garden, are back in our plant collection and bloomed recently. These members of the genus *Nepenthes* grow in the stove house of the growing ranges, and as soon as cuttings have been grown from the stock plants, these strange pitcher plants will be on display in the Climatron.

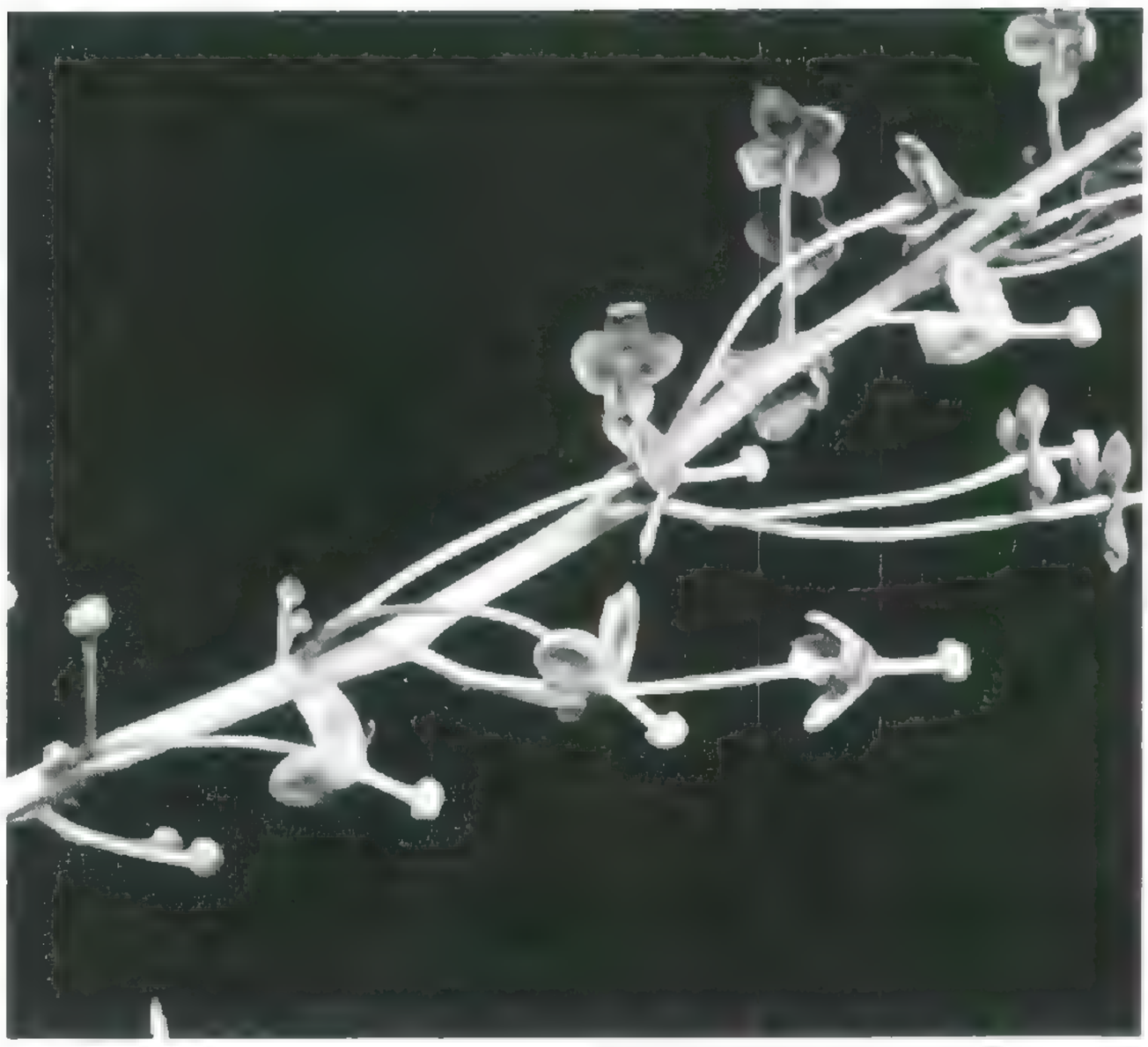
If we were to make a list of plant curiosities, *Nepenthes* would certainly be near the top. This vining pitcher plant, native to the Far East, attracts insects in two distinct ways and for two distinct purposes. In addition to attracting insects to the flowers for pollination, plants of the *Nepenthes* group attract insects to their odd-looking pitchers and consume them.

The pitchers, modifications of leaf midribs, have a lid and a thick rim which secretes a sweet substance and, inside the pitcher, many small stiff hairs that point down. Once an insect, attracted by the nectar-like substance on the pitcher lid and rim, enters the pitcher, it cannot escape, and drowns in the digestive fluid contained in the pitcher.

There are about seventy species of *Nepenthes*, occurring from South China to Australia, being most common in Borneo. All of these pitcher plants are climbers, with some growing as high as sixty or seventy feet. In their native habitat, their roots grow into the loose decaying debris of the jungle floor.

Nepenthes plants are dioecious, that is, the male and female flowers are on separate plants. The male or staminate flowers have four green, yellow, or red-tinged sepals that are about 3/8 by 1/4 inch in size and of rather thick texture. The inner surface of the sepals is closely dotted with honey glands that resemble the pitchers' rim

Lad Cutak



Claude Johnston

The pitchers of plants in the genus *Nepenthes* (left) are modifications of leaf midribs.

These male *Nepenthes* flowers (right), photographed at the Garden this year, have conspicuous sepals that are green, yellow, or reddish in color.

and lid glands. These secrete abundant nectar, often accompanied by a heavy musty odor, and attract small insects in great numbers. After feeding on the nectar and becoming dusted with pollen, the insects may feed on the equally attractive flowers of the female or pistillate plants, thus accomplishing the pollination needed for seed production.

Early interest in *Nepenthes* is seen in a paper, "The History of the Island of Madagascar" (1658), by a French botanist named Flacourt. Since that time many varieties of these odd pitcher plants have been discovered and collected in the Orient, from the Seychelle Islands in the Indian Ocean to the south of China to New Guinea, the Philippines, and Australia.

The greatest advancements in hybridizing these plants began in the 1860's when the James Veitch and Sons Company of London sent out collectors to obtain living specimens for an extensive breeding program. Soon crosses were being made with great success. Sir Joseph D. Hooker, the famous 19th Century English botanist and director of Kew Gardens, increased interest in *Nepenthes* by researching the structure of the pitchers and their ability to digest insects.

The demand for these plants increased to tremendous heights as new methods were found to propagate them. Kew Gardens for many years maintained a collection in a special *Nepenthes* house. Between the years 1875 to the early 1900's plants were distributed throughout England, France and the United States.

In 1899 a new hybrid was introduced by the Veitch Company; it was named *Nepenthes balfouriana*. Specimens of this hybrid, a descendent of four distinct species, flowered at the Garden in early fall. Unfortunately our *N. balfouriana* plants are both male.

George Pring, former Superintendent of the Garden, concluded that the Garden had one of the finest collections of *Nepenthes* in the world after touring European botanical gardens in 1948. The Garden's collection had begun in 1918 with a bequest of about a dozen plants from a private collector in Kirkwood, Missouri. Mr. Pring continued to expand the collection, hoping to develop a breeding program with *Nepenthes* as he had with the tropical waterlilies and orchids.

It was not until 1943 that he found both male and female plants in bloom at the same time. He obtained many cultivars from his crossings, including: Director George T. Moore, Lieut. R. Bradford Pring, Dr. Edgar Anderson, Dr. D. C. Fairburn, Gerald Ulrici, Katherine Moore, Joseph Cutak, Henry Shaw, St. Louis, and Nell Horner.

All of these cultivars have been lost to the Garden in the subsequent years, but recently we were able to obtain some new specimens of several *Nepenthes* species. We hope that soon, as in 1943, we will find both male and female plants blooming at the same time, and can develop some modern cultivars of this fascinating Asiatic pitcher plant.

The word *nepenthes* is Greek for "without care." Linnaeus made a remark while describing this genus: "If this is not Helen's Nepenthes, it certainly will be for all botanists. What botanist would not be filled with admiration, if, after a long journey, he should find this wonderful plant? In his astonishment past ills would be forgotten when beholding this admirable work of the Creator." His reference to Helen's nepenthes was from the "Odyssey," in which the drug nepenthe enabled men to free themselves of care and grief. □

Christmas Is . . .

Christmas is making your own decorations . . .
Christmas is collecting nuts, berries, greenery, plus odds and ends from other years and making your own decorations . . .

Christmas is making your own home decorations at the Garden's Christmas Workshop held each year under the leadership of Santa's Helper, Ken Peck (also known as Head of Education) . . .

Photographs by the St. Louis Post Dispatch

The Garden Gate Shop's Book Corner

Barbara Perry Lawton

IT'S NEXT TO IMPOSSIBLE for the lover of books, natural history, and gardening to spend only a few minutes in the book department of the Garden Gate Shop. It's more likely that a person will stop by the Shop after a visit to the Garden, intending only to browse, and go away with a new load of "books I must have."

The Shop expanded the book department at the end of 1970, and now has, in addition to the regular book rack in the main area, a Book Shop Annex. The Annex is a small quiet room off the traffic area where one can linger and select his choices from the many books that have been carefully chosen for the Garden's friends and visitors. In the enlarged shop that will be constructed this winter, there will be a much larger book room in addition to an expanded area where other articles will be displayed.

Books are unbeatable as gifts for Christmas as well as throughout the rest of the year. We have selected a few of the newer books for review in this *Bulletin*, and, in addition, will pass on some recommendations from Mrs. Edwin Stuessie, Shop Manager.

The Sierra Club's handsome pictorials that focus on such areas as the Big Sur and Navajo land are now available in paperback. There are many other soul-soothing picture books on famous gardens, historical homes, flower and plant arranging, and landscape design.

Euall Gibbons' "stalking books," such as *Stalking the Wild Asparagus* and his more recent *Stalking the Good Life* (David McKay), are very popular with amateur naturalists and respected by the scientists as well. In much the same vein are the books *Edible Wild Plants*, one by Fernald and Kinsey (Harper and Row), and the other by Medsger (Macmillan). Yes, they both have the same title.

Wyman's Gardening Encyclopedia (Macmillan) by Donald Wyman, the former head of Arnold Arboretum, would be a magnifi-

cent and definitive addition to any gardener's library. This is the newest in Wyman's series of books on botany and horticulture, having been published in the spring of 1971. Also for the gardener, especially one with an interest in organic gardening, is *Companion Plants* (Devin-Adair) by Philbrick and Gregg.

The Pocket Encyclopedias on cactus, indoor plants, roses, annuals and bulbs, perennials and water plants are a real bargain in hardback at only $4.95. These are part of the Macmillan Color Series and are profusely illustrated in color.

The many fine books on identification of plants and animals always sell well. The ultimate botanical authority for our area is, of course, Julian Steyermark's *Flora of Missouri* (Iowa State), but this is hardly a field guide, except perhaps for the jolly green giant, as it weighs a ton. It is a must as a reference in any good botanical library, whether it be one of ten books or one of thousands of books. In using the *Flora of Missouri*, you bring the plants to the book rather than vice versa.

Steyermark's *Spring Flora of Missouri* (Lucas) is another excellent, but more limited, reference. The same is true for another bargain publication, *Trees of Missouri* (University of Missouri Press) by Settergren and McDermatt, which sells for only $1.50.

The Peterson Field Guide Series (Houghton Mifflin) has been a howling success ever since it began with its *A Field Guide to the Birds*. This series now includes guides to almost everything in the natural world. Its *A Field Guide to the Wildflowers*, which is keyed to the color of the flowers, is great for the peripatetic beginner and casual botanist.

The Golden Field Guide series is a late starter, but is sure giving the Peterson Series a run for its money. Many staunch Peterson supporters are now using *Birds of North America* (Golden Press) which does have certain advantages, such as including all North American birds, descriptions next to illustrations, year round territorial maps, and diagrammatic descriptions of birdsongs.

All of the above books, plus those in the following reviews, as well as many more, are available through the Garden Gate Shop located at the Main Gate of the Missouri Botanical Garden on Tower Grove Avenue between Shaw and Magnolia.

For further information or mail order, call (314) 865-0440.

A review by Hugh C. Cutler

Gardens, Plants and Man

by Carlton B. Lees
(Prentice-Hall, $19.95)

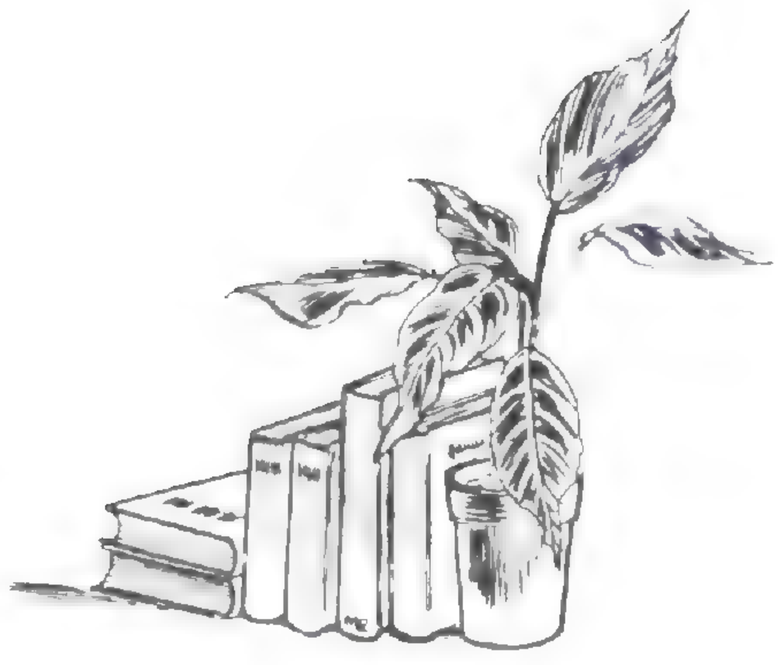
THIS IS A BEAUTIFUL BOOK of essays and illustrations for armchair and philosophizing gardeners. Lees begins with views of window boxes in the slums and the Governor's palace garden at Williamsburg. His main concern is the development and general effect of the great gardens. A series of plans, illustrations, and discussions traces garden development from Theophrastus and Hadrian to the famous gardens of France and England. A short chapter tells of recent developments of the public gardens in the United States. Some great herbals and the works of men like Bartram, Downey, and Olmstead, important in the development of gardens, are reviewed briefly.

As a contrast, in a gossipy two page account, he tells how a group of ladies, the Neighborhood Garden Association of Philadelphia, encouraged residents of low rent housing communities to erect and maintain window boxes and provided materials and continuing guidance. As the flowers grew, the occupants began to have more interest in caring for their homes and improving their neighborhoods. During the first year 427 window boxes were planted. Now there are more than 500 garden blocks, 16 community gardens, and 1,200 dooryard gardens in the project. The book has beautiful color plates, but the price ($19.95) is high.

Pictures of gardens and some essays with a similar approach are often printed in *Horticulture*, the magazine of the Massachusetts Horticultural Society, of which Carlton Lees is Executive Secretary. (*Horticulture* costs $6.00 per year, from the Society at Horticultural Hall, 300 Massachusetts Ave., Boston, Mass. 02115). Those who enjoy *Gardens, Plants, and Man* and *Horticulture* would also enjoy the varied viewpoints on landscape, city planning, gardens, and people, as published in the magazine, *Landscape*, (3 issues each year, $4.00; Box 7177, Landscape Station, Berkeley, Cal. 94707).

A review by Duncan M. Porter

Wild Flowers of the World



by Brian D. Morley
Paintings by Barbara Everard
(Putnam's, $15.00)

IN THESE DAYS of exorbitant book prices, few real bargains are available. This is one of them. Reproduction of Mrs. Everard's paintings is superb, and they alone are well worth the price. This is not to detract from the interesting and authoritative text that Dr. Morley has provided. *Wild Flowers of the World* is that rare sort of picture book that one can also sit down and *read*.

Morley begins with a concise introduction to plant nomenclature, morphology, classification, ecology, and geography, plus an historical essay which emphasizes botanical exploration. This section will be especially welcome to those unaware of botanical history. Too few of us know how and why we acquired the conglomeration of garden plants we grow today.

Following the introduction are three short sections devoted to acknowledgments, selected bibliography, and glossary. The bibliography is a good introduction to systematic and horticultural literature, although one could quibble about favorites left out or unfamiliar works included. The book might be easier to use if the glossary and the indices of scientific and common names were combined into a single index and glossary. The abbreviations of author's names used in the botanic index also would be more useful if some indication were given of the origins (countries or institutions) of the botanists listed. However, these are minor annoyances.

Everyone has his favorite flowers, and some of your favorites may not have been illustrated, but no one can object to those included. Most appear to be cultivated by at least a few gardeners outside their natural ranges. The paintings were done mainly in Malaya and at Kew and Wisley, and depict plants actually or potentially cultivated in Great Britain.

The plants are arranged systematically by family within geographic areas, first dicots, then monocots. Twelve geographic areas are represented in 192 plates, with an average of about five species pictured on each plate.

Opposite each plate is a page full of information about the species illustrated, which contains the real meat of the book. Names —common (at least for the English), scientific, and synonymous— are given. The sometimes extensive discussions cover relationships, morphology, history natural and unnatural, uses, and occasional notes on cultivation.

Many books of this type are written by amateurs who may have a profound knowledge of the cultural aspects of the plants discussed, but who often use nomenclature that is unfathomable, especially when discussing horticultural plants. Brian Morley, happily, is a professional taxonomist who is able to avoid this unpleasantry. He also appears to be a far more knowledgeable gardener than the average taxonomist.

My only adverse comment about the plates is that they are too few. The discussions of the flowers do not follow the illustrations in order, but as they are opposite the plates they discuss, the annoyance is trivial. The only typographical errors of significance are on Plate 150, where the symbols for *Magnolia virginiana* and *Illicium floridanum* have been switched, and in the discussion of Plate 172, where the symbols for *Centropogon cornutus* and *Lisianthius umbellatus* have been transposed.

The plants pictured range in size from the diminutive pink-flowered *Simingia pusilla*, a South American gesneriad that "can be grown in a thimble," to *Dipterocarpus trinervis*, an Indonesian forest tree which grows to 230 feet or higher. They range from our everyday *Catalpa bignonioides*, the cultivated and naturalized Indian bean, or *Rosa setigera*, the beautiful prairie rose, to *Couroupita guianensis*, the tropical cannon-ball tree, with its bizarre reddish flowers and huge smelly indehiscent fruits, *Chianthus formosus*, Sturt's desert pea, from Western Australia, with its red-bodied and -headed, black-faced pixies for flowers, and finally to *Rafflesia*, that Malayan and Indonesian genus of root parasites which has flowers fully a meter in diameter. This list could easily be extended until at least one plant from each plate is included, but I'll stop here. Spend $15 to buy the book, and see for yourself the tremendous diversity of the flowering plant world.

A Review by Sandra Thornton

Bamboo

Robert Austin and Koichiro Ueda
(Walker/Weatherhill, $15.00)

MOST OF US ARE UNFAMILIAR with bamboo except for glimpses here and there, perhaps at a flower show or in a friend's house where it is used for such things as curtains and place mats. We usually appreciate it when we see it, but to buy bamboo plants or articles we have to go to a special store or an import house. In the Orient bamboo and utensils made of it are so common it's hard to imagine life without it. *Bamboo*, a large handsome book by Robert Austin and Koichiro Ueda, is a most enjoyable way to learn about what we're missing.

Bamboo is divided into three sections—lore and versatility, beauty and uses, and growth and cultivation. The first and last sections are mostly text including surprising facts about bamboo, such as the phenomenal growth rate of almost four feet a day for some species. It is actually a woody grass, hollow on the inside, with a wall at each node which divides the stem, or culm, into compartments. Like other grasses it flowers, but unlike them it dies soon after flowering. This fact is especially important to commercial growers of bamboo, because it can take a grove ten years to completely come back after flowering. Information like this is presented in such a concise yet comfortable way it gives the history of bamboo and its cultivation in two relatively short sections.

The visual appeal of this book comes from the large middle section with over 160 of Dana Levy's excellent photographs, many of them in color. There are pictures of ordinary, everyday articles such as writing brushes, ladles, flutes, baskets, carved boxes, chopsticks, umbrellas, spoons, hats, fishing poles, rakes, rice tasters, and fish tubs. Each photograph has been taken with such an eye for composition and the natural beauty of bamboo that you feel as if you're browsing through an art gallery. There are also several series of black and white photographs with descriptions showing step by

step the craftsmanship involved in making handcrafted products like bows and arrows. Altogether, it's the photographs that make *Bamboo* such a pleasure to page through. Occasionally captions aren't clearly linked to pictures, but the photographs are so striking and self-explanatory that many times descriptions are unnecessary.

A Review by Mary E. Baer

Bouquets That Last

Emily Brown
(Hearthside, $10.00)

THE UNDERLYING THEME of this informative book is "respect for nature." That it achieves its purpose is revealed in the contents of its twelve chapters. To name a few: "Prolonging the Life of Flowers and Foliage," "Glycerinizing and Shellacking for Permanence," "Making Renewable Arrangements," and others that include the care and composition of fresh flowers, the drying for winter bouquets, the use of rocks, shells and wood to enhance a modern composition. The chapter "Plant Lists" consumes almost a third of the book. The use and treatment of each plant is described and thoroughly detailed.

The colored plates of flower arrangements are of such magnitude and beauty that they come alive and are truly superlative. For each of the seventy-three there is a full description.

The book is written in depth for a novice and yet contains knowledge sophisticated enough for the professional. Emily Brown is a nationally known horticulturist, garden consultant, writer, lecturer, and flower show judge. She serves on the boards of the deYoung Museum and the Stryling Arboretum in California, where she lives.

Mr. Jack Napton is the photographer, and is also a knowledgeable specialist in the plant world, as well as a board member of the Stryling Arboretum.

A Review by Marjorie Richardson

Making Gifts from oddments and Outdoor Materials

Betsey B. Creekmore
(Hearthside, $7.95)

HERE IS A BOOK for people who enjoy nature, like to collect nature's bounty, and then wonder what to do with the collections. There are dozens of suggestions, from how to successfully send your own garden fresh flowers to how to make pseudo-topiary frames in fanciful forms. Several chapters explain drying, curing, preserving, and using flowers and leaves. Floral Easter eggs, dried flowers in glass bottle tops, Victorian arrangements under glass domes, pressed flower pictures, and decoupage projects are among the many suggestions. "Glass" flowers made from liquid plastic inspire lovely gifts: jewelry, domed paperweights, buttons, flowered drawer pulls, door knobs. There are suggestions for laminating plant materials between plastic for place mats, screens and room dividers.

The chapters utilizing pine cones, seeds, pods, and nuts are especially helpful to the gatherer who can't resist collecting fall's fruits. Here are ways to use all those pine cones stashed away in the basement! There are explicit directions for making and good suggestions for using many different kinds of coneflowers. (I liked Mrs. Creekmore's admonition about using restraint with gold paint!)

After seeing the fetching photograph of a cornhusk doll, I was inspired to save every husk from the summer's corn, thereby starting a new collection. Fortunately, this book tells me what to do with it—dolls, Christmas angels, flowers, rosettes. Doll fanciers will also learn how to make dried apple-head and gourdhead dolls.

Chapters on herbs and seasonings, scented gifts, waxed flowers and candles, holiday decorations are all included in this good "how to" book. There is a listing of 116 different flowers and foliage and how to preserve them in the appendix. □

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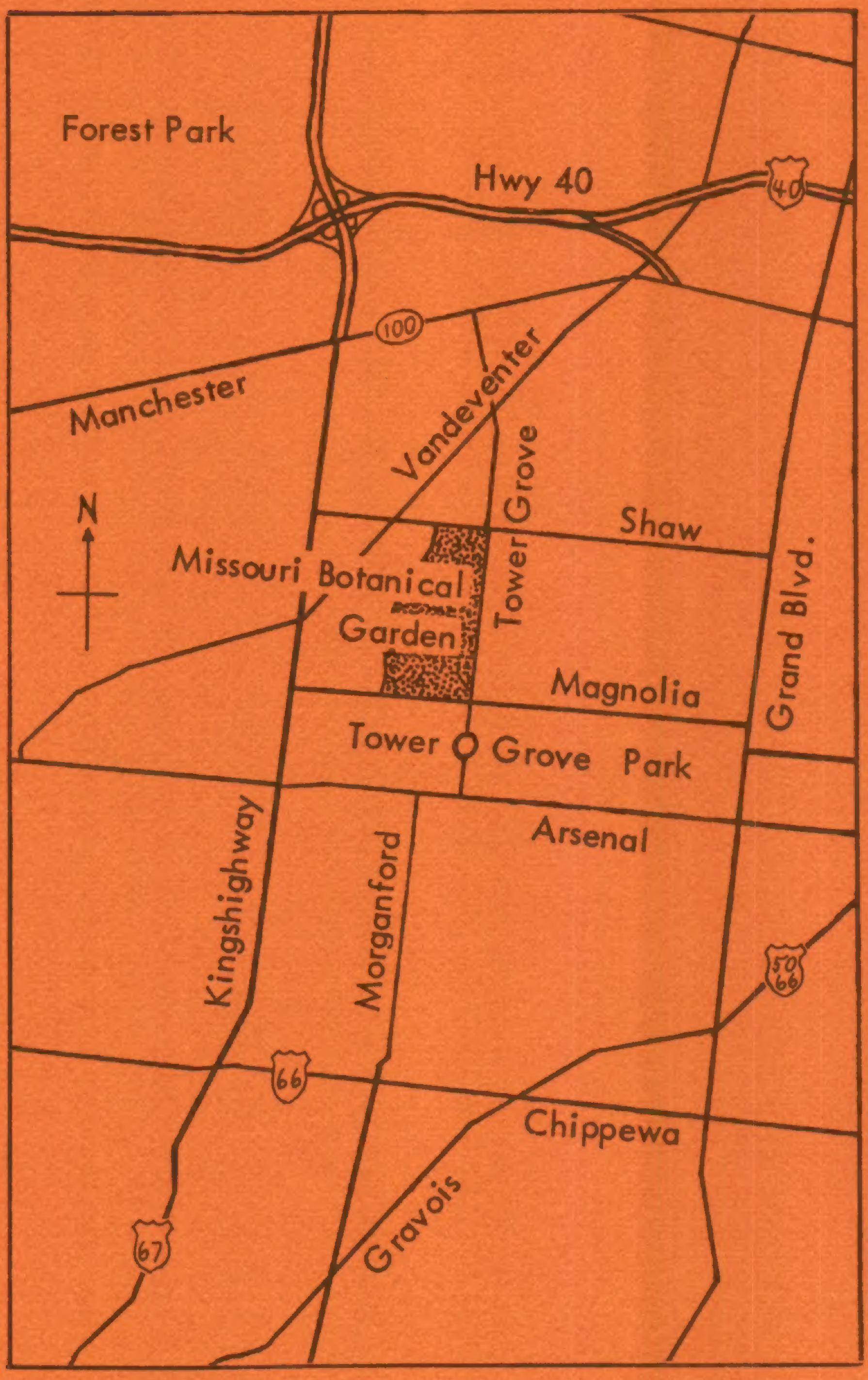

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